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GEOLOGICAL SURVEY OF KENTUCKY.

EASTERN COAL FIELD.

C

COMPRISING EIGHT REPORTS ON THE RESOURCES OF SOME OF THE COUNTIES LOCATED IN THE EASTERN COAL FIELD.

STEREOTYPED FOR THE SURVEY
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CONTENTS.

[The figures refer to bottom paging.]

PREFACE TO SECOND EDITION (NEW SERIES,.

It being necessary to publish a new edition of the Reports of the Geological Survey, it is thought proper to change the arrangement of the reports in the several volumes. This is advisable in order to bring together in one volume the several reports relating to a given subject or locality. In the first edition (second series) the volumes were made up of reports, regardless of subjects treated, and in order to learn all that may be published of a locality, the reader must examine several volumes. For instance, the reports on the iron ores and the iron manufacture of Greenup, Carter, Boyd, and Lawrence counties is in volume 1, and the Report on the Geology of the above named counties is in volume 2. The Chemical Reports and the reports on the Timbers are scattered through four volumes. This arrangement of reports could not have been avoided in the early history of the Survey without a delay in the publication of the volumes. It is thought that the arrangement in this edition will more fully meet the wants of the public, and will render the reports more valuable.

The first volumes of this edition will comprise the following: Chemical Analyses, Reports on the Eastern Coal Field; Reports on the Western Coal Field; Reports on Timbers. Other volumes will be published from time to time, preserving the same order of grouping reports. Some of the preliminary reports contained in the first edition have been omitted, in order that there may be no duplication when the final reports are published. I am of the opinion that enough preliminary or reconnoissance work has been done by the Survey, and the work will be directed with a view of securing (so far as the means will permit) complete reports on the geology, soils, timbers, etc., of the various regions

studied. As the stereotyped plates of the omitted preliminary reports are preserved, new editions may be ordered should there be a demand for them. A change has also been made in the size of the volume by decreasing the size of the margin, which, it is thought, will make the volume a more convenient size, both for library use and for sending through the mails.

JOHN R. PROCTER,
State Geologist.

GEOLOGICAL SURVEY OF KENTUCKY.

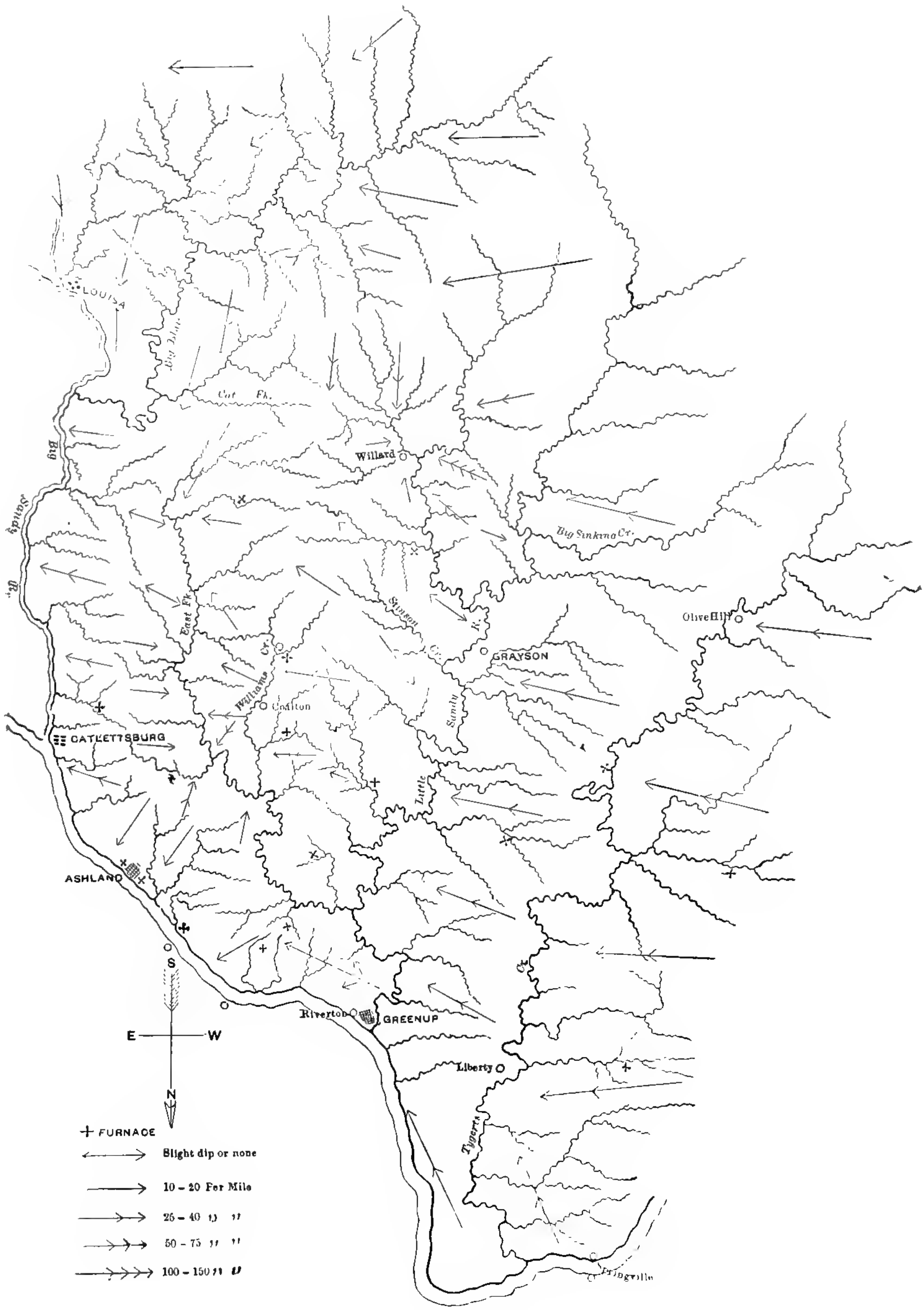
N. S. SHALER, Director.

REPORT ON THE GEOLOGY

OF

GREENUP, CARTER, AND BOYD COUNTIES, AND A PART OF LAWRENCE,

BY A. R. CRANDALL, Assistant.



LOUISA
Big Blaine
Cat Fk.
Big
Sandy
R.
Willard
Big Sinking Cr.
East Fk.
Stinson Cr.
Williams Cr.
Olive Hill
GRAYSON
Coalton
Sandy
CATLETTSBURG
Little
ASHLAND
S
E
W
N
Riverton
GREENUP
Liberty
Tygerts
Cr.
+ FURNACE
Slight dip or none
10 – 20 Per Mile
25 – 40 " "
50 – 75 " "
100 – 150 " "

REPORT ON THE GEOLOGY OF GREENUP, CARTER, AND BOYD COUNTIES, AND A PART OF LAWRENCE.

The coal measures of Eastern Kentucky are represented, in the counties included in this report, by rocks which have an aggregate thickness of about 900 feet. These rocks rest on the sub-carboniferous limestone, or, in its absence, on the lower carboniferous sandstone and shale, at such an inclination as to present the whole series, included in this thickness, in an upward order, along any line from the limstone-capped hills west of Tygert's Creek to the Chatterawha or Big Sandy river. Variations in thickness of the different parts of the series, and also in the aggregate thickness, are found along different lines; but the order is generally preserved, with no considerable disturbances to complicate the problems involved in a study of this part of the coal field.

A brief description of the underlying formations will serve to make the geological position of the coal and iron-bearing rocks plain, and also to throw some light on the question of the inclination or dip, to which reference has been made.

To facilitate a study of these lower rocks, a profile section is given, which shows the order of superposition and the thickness of different formations along the located line of the Lexington and Big Sandy Railroad, from the Licking river to the mouth of Soldier's Fork of Tygert's Creek. The Upper Silurian rocks, which cap the hills around Owingsville, and which bear the iron ore deposits of Bath county, fall below the drainage at the Licking river. The Devonian black shales form the base of the hills east of the river. The thickness of these shales is not clearly shown; but the base of the overlying formation, the Waverly sandstone, is about 150 feet above

the bed of the river, which is formed in the limestone of the Upper Silurian, apparently near the top of the formation. The Devonian shales at this point are clayey, somewhat bituminous, and are interesting chiefly from the effect which they have in giving character to the topography of the country.

The Waverly* sandstones and shales, or the knobstone formation of Mr. Joseph Lesley has a thickness of 400 feet in this section. At Springville, and on Indian Run, in Greenup county, over five hundred feet of this formation is shown, and it is probable that the whole thickness is considerably greater. The thickness in the eastern part of Montgomery county, in the opposite direction, is given by Mr. Lesley as 330 feet. In Ohio this formation has been found by Mr. Andrews to have characters which warrant a division into three parts. South of the Ohio river, however, such natural divisions are not so apparent, the whole series being made up of fine-grained sandstones and shales, generally of an olive-greenish color, but with occasional bands of red and of whitish shales. At the base, and at various other levels, fine building stone is found, which has already acquired a wide reputation. Fossils are abundant in many parts; but the most characteristic impression is that of a Fucoid, the form of which, resembling somewhat the cocktail, is readily recognized, and not easily forgotten. It is not found in the coal measures above, and therefore, in the absence of the sub-carboniferous limestone, it serves to mark the transition from the coal-measure to the Waverly rocks, the line of which is often without other distinctive marks.

Going eastward along Triplet Creek, the Waverly rocks form the whole height of the hills at Morehead, in Rowan county, the Devonian shales having fallen below the drainage. The hills to the east of Morehead are capped by a coarse hard sandstone, at the base of which a thin band of cherty limestone is found in some places. These are the outlying representatives

* I have preferred the name Waverly to that of knobstone, for the reason that the latter term is likely to lead to confusion from the fact that other formations give rise to a topography equally or more knobby; as illustrated by the "knobs" of East Tennessee, in the Lower Silurian, the knobs of Owsley county in the coal measures, and other instances. The former name is without particular appropriateness, but is the one adopted in the Ohio reports, and is as widely known as any perhaps, and therefore has some claim to general use.

of the sub-carboniferous limestone and the conglomerate sandstone, both of which have a considerable thickness to the east and south. The latter becomes particularly conspicuous over a large area of country. The dip of the rocks is slight from Licking river eastward; the rise of the bed of the creek accounting in part for the disappearance of the lower rocks. East of the divide between Triplet and Tygert's Creeks, the base of the limestone is found, at the mouth of Soldier's Fork, only about 75 to 80 feet above drainage; giving a fall of about 320 feet in 24 miles, or nearly 14 feet to the mile along this line. The dip does not appear to be greater more directly east or south of east, as may be seen by the height above tide of the top of the Waverly in section 4, plate No. 2.*

The Waverly sandstone is shown in most of the sections given west of the divide between Little Sandy river and Tygert's Creek. The inclination is such that this formation falls below the Little Sandy, except near the Ohio. At the mouth of the Little Sandy it rises from 15 to 20 feet above low

*The sections on plates 1 to 24 are arranged with reference to tide level. Low water at the mouth of the Little Sandy river, or 485 feet above the sea, is chosen as the base, and the figures at the left of the plate reckon up from this level. The locality of each section is indicated by a number on the map corresponding with the number of the section. A good idea of the position and dip of the various rocks in this region may be obtained by a study of these sections in connection with the map. But to present the main facts in a more ready form, profile sections are also given, extending across the field in three lines; the first from the Ohio, below Springville, in Greenup county, to Catlettsburg, in Boyd county. The second, from Kenton Furnace, in Greenup, to the mouth of the Bear Creek, in Lawrence county. The third, from Boone Furnace, in Carter county, to Louisa, in Lawrence.

The determination of the height from tide, and also above drainage, has been greatly facilitated by the numerous railroad surveys that have been made in this field. Repeated barometric measurements have, for the most part, supplied the details; the hand-level being used sometimes, and such other means as could be made available.

The abreviations made use of in the sections are as follows:

S. S., sandstone.
L. or L. S., limestone.
S., shales.
S. S. S., shaly sandstone.
Cong., conglomerate; Cong. S. S., conglomerate sandstone.
C., coal; C. C., cannel coal.
F. C., fire-clay.

Sections on plates numbered 24 to 30 are not arranged to indicate height above tide. In each column the natural succession of rocks is shown. When two sections from different localities are included in the same perpendicular column, they are joined on some identical coal or ore; as in sections 5 and 6, on plate 26, where an oblique space indicates the top of one and the bottom of the other; or where all the rocks of the series, from the base of one to the top of the other, are not included, the intervening space represents the normal thickness of the rocks wanting, unless it is otherwise indicated by including lines, or by statement on the plate to the contrary.

water. It is not seen further eastward than Riverton, where it is exposed at low water.

The limestone formation, which follows the Waverly in the order of superposition, is wanting or very thin over a large part of Greenup county. Section 25, plate 9, near the mouth of Little Sandy, shows no trace of limestone. On Coal Branch a few inches of calcareous rock is shown. (Section 1, plate 29.) A thin layer of limestone is found on Smith's Branch. The hills back of the lime-kilns show the only considerable development of this formation near the Ohio. Here the deposit reaches a thickness of 35 feet at one point; but it rapidly falls away in thickness, so that outside of an area of a few square miles, only a thin cherty rock occurs to represent this formation; and often this is entirely wanting in the neighboring hills. The hill back of Springville shows no limestone. (Section 5, plate 3.) At the head of Indian Run a cherty bed several feet in thickness occurs. (Section 1, plate 2.) Fragments of a similar bed, in the valley of Montgomery Creek, show its extension into Lewis county, where the hills, for some distance westward from Greenup, are capped by rocks similar to the outlying rocks of Rowan, as mentioned on a previous page. Southward the sub-carboniferous limestone increases in thickness from a few feet, at the head of Shultz Creek, to 140 feet, at a point on Tygert's Creek near Carter Caves. (Section 20, plate 6.) On Kenton Furnace lands 10 to 20 feet is shown. (Section 12, plate 5.) On Boone Furnace lands from 80 to 100 feet is exposed, and this thickness is repeated or increased along Tygert's Creek southward to the divide between Tygert's Creek and Big Sinking Creek. Westward from Tygert's Creek, this formation rapidly loses its importance. To the eastward, also, it thins out nearly as rapidly. (Profile sections II and III.) A considerable thickness of limestone is reported, however, in some of the wells drilled in the Big Sandy valley, near the southern line of Lawrence county. The effect of the thinning out of this formation eastward is an increased inclination of the overlying rocks towards the east, and a corresponding limitation of the area in which

a given thickness of rock is exposed by the drainage of the Little Sandy. The decrease in thickness northward also tends to increase the inclination of the overlying rocks in that direction. The fall towards the Ohio river, a little east of north, is about the same as that of the general surface of the country, and, in general, the disappearance below drainage of rocks of the same geological level is along a line running nearly north-northeast and south-southwest. In the southern part of Carter and Lawrence counties the dip is changed to the north; the underlying rocks to the southward being elevated or thickened so as to form, with those along the western side of this field, two sides of a geological basin.*

The top of the Waverly, near Morehead, where the place of the limestone is shown, is about 1,150 feet above tide. At the head of Indian Run the height above tide is about 1,000 feet. At the most western outcrop near the Ohio, of the conglomerate formation and the thin representative of the sub-carboniferous limestone, the height would reach 1,050 feet, a difference of 100 feet in a distance of 30 miles, or an average fall towards the Ohio river of three and one third feet to the mile. Besides the general inclination of the top of the Waverly, it is characterized by undulations, which, together with the varying thickness of the sub-carboniferous limestone, give to the base of the coal measures an irregularity which is not only very noticeable, but which sometimes leads to confusion in the order of the overlying beds. The sub-carboniferous limestone, when present in considerable thickness, is usually made up of rocks varying in character from a pure white or grayish limestone to that which is sandy or ferruginous or cherty. The former rock makes an excellent quicklime, as shown by the demand for the products of the lime-kilns on the Ohio, in Greenup county. At some points a thin bed of what may prove to be lithographic stone of good quality, has been noted. At the bridge across Tygert's Creek, near Olive Hill, on the old State road, a thickness of eight inches is shown

*Whether to the east of the Big Sandy, and near the Ohio, the rocks dip to the westward, forming the third side of a great geological basin, has not, so far as I can learn, been fully determined, but there seems to be strong indications that this is the case.

near the level of the bridge, and about 25 feet above the base of the formation. The notion prevails to some extent, that silver may be found in these rocks; but any effort to find the precious metals must necessarily result in disappointment. This remark applies equally well to all the formations in this region.

THE COAL MEASURES.

At the top of the sub-carboniferous limestone, and resting upon it, is the so-called "limestone ore," or "lower limestone ore." With this ore, which is one of the most valuable in Eastern Kentucky, the coal and iron-bearing rocks begin; though, strictly speaking, from its association with the limestone and its limitation to the area of this formation, the ore itself might perhaps be regarded as belonging to the sub-carboniferous period. The character of the ores of this section are fully discussed by Mr. Moore in his report on the ores of this part of Kentucky.

The coal-measure rocks of Eastern Kentucky are readily separated into minor divisions by characteristic rocks at different horizons. What the relation of these natural divisions is to those which are found in localities widely separated from this field, is a question that may be left for future consideration; the present purpose being as well subserved by a statement of the facts as they are found in this field. The names which have come to be used to designate these rocks will be retained, however, without assuming the equivalency which they suggest. The conglomerate formation, as described by Mr. Lesley, is the lowest division, and varies in thickness from a few feet, as shown near the mouth of Tygert's Creek, to 100 feet or more, as exposed on the Big Sinking. It usually occurs as a coarse ferruginous sandstone; but at various points, and more especially to the southward, it is a true conglomerate, or is banded with pebbled layers. At some points in Greenup and Carter this rock is found resting immediately upon the sub-carboniferous limestone (section 2, plate 3), but generally it is separated from that rock by shales varying

in thickness, nowhere in these counties exceeding 30 to 40 feet. These shales, which constitute the sub-conglomerate member of the series, become thicker and include a number of important beds of coal, to the southwest. In Greenup and Carter one thin bed is found. The rocks above the conglomerate are more uniform in thickness, as shown by measurements between well-known beds of coal at different points, but they are also much more varied in character. Shales and sandstones frequently interchange with each other in such a way as to greatly disguise the real stratification of this region. In general terms, the coal measures above the conglomerate may be said to be made up of, first, a shale formation of from 50 to 100 feet, resting on the conglomerate, a series in which shales largely predominate, and which include Coal No. 1, and one or two block ores. (See general section, plate No. 1.) Second, a sandstone series, or one in which the sandstone makes up a large part of the whole thickness, or from 240 to 340 feet. This series includes Coals 2, 3, 4, 5, and 6, with two block ores, and the so-called limestone and limestone kidney ores. Above, shales again predominate, in a third series of rocks largely made up of greenish shales, with shaly sandstone, which have a thickness in Greenup, Carter, and Boyd counties of 90 to 120 feet. In some parts of Lawrence this series is almost entirely wanting, or replaced by coarse sandstone. Coals 7 and 8 and the kidney ores, with the so-called "bastard limestone ore," are included in this formation. Above these shales, a coarse ferruginous sandstone, sometimes banded with conglomerate layers, is usually found in varying thickness—the Mahoning sandstone of Owen and of Lesquereux. This, with the overlying rocks, which are largely shales and shaly sandstone, with beds of impure limestone, but which in some places appear in an almost unbroken series of sandstones, adds to the coal measures of this section a thickness of nearly 400 feet. Sections 71, plate 19; and 81, plate 21; and section 6, plate 25, show a large part of this series, which reaches to the tops of the hills along the Big Sandy. It includes Coals

9, 10, 11, and 12; the so-called Rough-and-Ready ore, with other ores of less importance.

COALS, ORES, AND FIRE-CLAYS.

Beginning at the base of the coal-bearing rocks, a thin coal is found near the sub-carboniferous limestone, or, in its absence, near the Waverly sandstone, as at Olive Hill, in Carter, and Coal Branch, in Greenup, and at other points; and though the conglomerate formation is wanting over a part of Greenup, where this coal is shown, yet it should doubtless be regarded as a sub-conglomerate coal. As the coals below the conglomerate are known to have a considerable development elsewhere, this bed is left to be numbered with them. It is mentioned in reports of the old Survey as Coal No. 1 A, being erroneously regarded as the same bed as that found on Chinn's Branch, and at Steam Furnace, &c. (Volume IV, page 410.) The bed of non-plastic fire-clay, which occurs near this horizon, is also a sub-conglomerate bed. (See section 2, plate 29, and section 28, plate 8.) Like the coal with which it is sometimes closely associated, it is often entirely wanting at points where the conglomerate sandstone follows the limestone, without an intervening bed of shales of considerable thickness. This is the same fire-clay as that used at Sciotoville, in Ohio. The value of the deposit can hardly be estimated at present. It is of fine quality, and inexhaustible in quantity. An analysis of an average sample, taken from an exposure at Boone Furnace, shows the following result:

UPPER PART OF BED.

Silica	48.56
Alumina	37.471
Iron oxide	a trace.
Lime	.112
Magnesia	a trace.
Phosphoric acid	.255
Potash	.289
Soda	.283
Water expelled at red heat	13.030

Other analyses show a larger per cent. of silica. (See the last report of Dr. Peter.) This bed has a thickness of four to six feet. On the place of Mr. Ratcliff, near the lime-kilns, a

thickness of eight feet is shown, but the additional thickness is of poorer quality apparently. The bed is found over nearly all of that part of Greenup and Carter counties which presents the rocks of this horizon above drainage. (See sections 1 and 4, plate 2; sections 5, 7, and 8, plate 3; section 9, plate 4; section 19, plate 6; and section 25, plate 8, in addition to those referred to above.) It has also been noted further southward, along the western outcrop of the coal measures. It is mined and shipped in large quantities to Cincinnati from the head of Indian Run, in Greenup. It is reasonable to suppose that this deposit will in time become one of the important sources of wealth to this part of Kentucky.

Above the conglomerate sandstone, in the shale series which follows it in the order of succession, are several ore deposits of greater or less range, and also a coal bed, which, from its wide range and its quality, will prove one of the most valuable in Eastern Kentucky. In thickness this coal is variable, being, in some places near the Ohio, too thin to work with profit, except for local purposes. It appears to be the equivalent of the Jackson shaft coal in Ohio; and as it is the first coal above the conglomerate, and the first of any importance in this part of the coal field, I have designated it Coal No. 1, or the first in a series which includes all the coals of importance in this section, including also those above the so-called Mahoning sandstone. This separation of the sub-conglomerate coals from those above, while no division is made on the Mahoning sandstone, is adopted simply as a matter of convenience. The sub-conglomerate formation, not having been worked up, is left to be considered by itself. The rocks above have been carefully studied, and, as seems most convenient for practical purposes, the beds are numbered in a continuous series, without reference to any division into periods, the equivalent or otherwise of those demonstrated in other parts of the continent. Coal No. 1 has been opened and worked at a number of points in Greenup county. Near the foot of the hill back of Greenup it is 12 to 18 inches thick. Back of Riverton it is near the bed of the creek. Eastward from this point it falls

below drainage. (See profile section No. I.) At Raccoon Furnace it is 30 inches thick. On the Little Sandy, nearly opposite Buffalo Furnace, a thickness of three feet is shown, with a clay parting separating it into about equal parts. On Barrett's Creek it is about the same thickness, without parting. A bed of coal recently opened by Mr. Pierce, near Hopewell Station, is probably the same coal. Near Willard, on Little Fork, this coal is three and a half feet, with an inch of slate near the bottom. To the eastward from all these places, this coal soon falls below the drainage; to the west it is found, along with the dip of the formation, in varying thickness, but generally thinning out towards its most western exposure, in the tops of the hills along the line between Greenup and Carter on the one side, and Lewis and Rowan on the other.

The change in the dip of the rocks mentioned on a previous page, brings this coal above drainage further eastward, south of Willard. It is exposed near the head of Dry Fork, near the bed of the creek. On all the upper branches of Blaine Creek, and on Little Blaine and George's Creek, always in shales, and here about 60 to 70 feet above the conglomerate, as shown at the mouth of Hood Creek, and along Blaine for some miles above, where the conglomerate comes to the surface, as also on Brushy Creek, between Mr. Holbrook's and Mr. Swetnam's, where the conglomerate rises to a height of 25 feet above the bed of the creek; on Hood Creek, where the cliffs reach a height of 80 feet, and on the Laurel Creeks, where the cliffs of conglomerate reach a height of 120 feet (see section 8, plate 3; sections 9 and 10, plate 4), and on Keaton's Creek, where, at one point near the mouth, the conglomerate rises 20 feet above the bed of the creek, the coal always occurring at about the same distance above the conglomerate. The shale series above the conglomerate is greatly thickened up in this direction, and includes several bands of calcareous rock and many lozenge-shaped blocks of calcareous rock imbedded in the shales.

Northward, along Blaine and Brushy Creeks, Coal No. 1 falls below the drainage. Its furthest exposure northward in the

valley of Blaine is at Haw's Mill, at the junction of Brushy Creek with Blaine. At Mr. Graham's, near the mouth of Cherokee, it is carried below the bed of the creek by a downward bend of the rocks. Probably the coal shown in the bed of Irish Creek may be referred to this bed. Eastward, from Hood and Brushy Creeks, the conglomerate disappears below the drainage, and Coal No. 1 falls to near the bed of the main streams. It is opened at several points on George's Creek, and on Little Blaine. It is not opened immediately on the Louisa Fork of Sandy, in Lawrence county, that I can learn, but would be found near low water, probably. At Warfield, on Tug Fork of Sandy, in Martin county, it is the main coal, and near high-water mark. At Flat Gap, in Johnson county, this coal is found in good thickness near the base of the hills. It is below the drainage in all the country drained by Rockcastle Creek and to the northward between the Forks of Sandy. Southward, from the line of Lawrence and Johnson, the change of level is slight along the Louisa Fork at least, No. 1 Coal being near high-water mark at Prestonsburg. It is probable that the dip to the east, which follows the disappearance of the conglomerate sandstone eastward from Hood Creek, will be found to continue in the belt of country to the southward, along Louisa Fork.

In thickness, Coal No. 1 varies in different sections; but so far as developed, it has a local uniformity which promises to make mining easy and profitable at these points when it reaches a workable thickness. Openings already made show 15 inches near the Ohio; three feet at the Hanna bank; about the same thickness on Barrett's Creek; three and one half feet near Willard, on Little Fork, and on Dry Fork, about three feet on Deer Creek west of Willard in the Little Sandy valley, two to three feet on the head waters of the Blaine, and on George's Creek, and at Warfield five feet. At all these points, except the Hanna bank, it is without any considerable parting. At some points it has no underlying fire-clay. (See plate VII.)

This coal is no exception to the general rule as to variation in quality at different points. It ranks with the best coals,

however, as will be seen from analyses by Prof. Peter and Mr. Talbutt, of average samples taken at two points, which show the range in quality in Carter and Lawrence counties. Two samples carefully averaged* from Little Fork, near Willard, show the following results:

Specific gravity	1.269	
Moisture	3.50	3.60
Volatile combustible matter	36.00	35.40
Fixed carbon	57.30	57.60
Ash	2.90	3.40
Sulphur	1.145	1.108

Sample from Mr. Swetnam's coal, on Brushy Creek, gives a still better result. The ash is doubtless too low. Near the Ohio river this coal is less reliable in quality than in Carter

* A remark on the method of collecting samples of coals for analysis is made necessary by the seeming excess of ash and of sulphur, which will be noticed in some coals known to be of superior quality, and of which analyses have been made on a different plan of sampling. In all instances, the aim has been to secure an average of the whole thickness of the bed to be represented, or of different parts of the bed, including all impurities that would not be separated from the coal in the ordinary process of mining. When practicable, this has been repeated, at different points in the same mine, to average as nearly as possible the variations that are found at different points in the same entry. Unless this is fully understood, the result of comparison with the analyses of coals of other States will be an unfavorable impression of the quality of the coals of Kentucky, while in reality they do not suffer by comparison. Analyses of the best coals from neighboring States, collected in the same way, are given by way of comparison. It is taken for granted that practical men desire to know the average quality of coal as it goes to market in bulk, rather than to know how pure it can be made to appear on paper; and though in attempting to obtain samples to this end, there is a likelihood of giving too large a per centage of impurities from the increased proportion found in that part which becomes slack by exposure, and is eliminated to some extent by handling, and also from local variations; yet this average carefully made is more likely to be near the true representation than samples as ordinarily taken. The analyses of the coals of Eastern Kentucky were made from average samples, taken by Mr. Moore or myself, unless otherwise stated, as also were the analyses of coals from other States, which are introduced by way of comparison.

The following table shows how imperfectly a single block of coal represents the whole bed:

	No. 6. Turkey-pen Hollow.		No. 7. Pritchard's coal.	
	Average.	Single block.	Average.	Single block.
Moisture	3.40	4.70	5.40	4.50
Volatile combustible matter	32.30	34.30	32.70	37.10
Fixed carbon	55.40	59.04	52.52	56.40
Ash	8.90	1.90	9.38	2.00
Sulphur	1.23	.983	2.306	.571

The difference shown in the proportion of ash and of sulphur is such as should be expected in any bed of considerable thickness. When an attempt is made to select a block that is an average of the whole bed, in quality, the difference would be less perhaps; but aside from the impossibility of selecting an average sample in this way, the personal bias is always on the side of the best specimens, and the result of comparison with a sample carefully taken from the whole face of the bed would, in nearly every instance, be very much like that shown in the table.

and Lawrence. The following is the result of an analysis of Mr. Swetnam's coal:

Specific gravity	1.281
Moisture	5.10
Volatile combustible matter	35.30
Fixed carbon	57.80
Ash	1.80
Sulphur	0.73

An analysis, by Dr. Peter and Mr. Talbutt, of a sample collected by myself at Jackson, Ohio, at a point in the Star Furnace mine where the coal was regarded by the superintendent of the mine as equal in quality to any in that region, gives the following result:

Specific gravity	1.361
Moisture	4.54
Volatile combustible matter	29.68
Fixed carbon	58.86
Ash	8.72
Sulphur	0.756

The Jackson shaft coal has already acquired considerable reputation as an iron-making coal. In Kentucky no trial has been made of this coal for this purpose. Steps have been taken towards the mining of this coal near Willard, and I understand that it will be used for iron-making. The Warfield and Prestonsburg coals appear to be fully an average in quality, while considerably increased in thickness. This coal is not mentioned in the old report on Greenup and Carter.

Coal No. 2 is of less importance in this field than Coal No. 1, being less trustworthy, both in thickness and in quality. It is present, however, over a wide range of country, and on Everman's and Barrett's Creeks (Kibby's, Jones's, and Lewis's coal), in Carter county, it is found in workable thickness and of very good quality. This coal has been opened on a small branch back of Riverton (see section 4, plate 27), where it showed a thickness of two and one half feet at the outcrop, but soon disappeared on account of a slide of the rocks, and no further effort was made to ascertain the value of the bed. On Ulin's Branch, twenty-five feet above the bed of the branch, a thickness of two and one half feet is shown in two parts, separated by seven inches of clay, and immediately under a thick-bedded sandstone. This coal is spoken of as Coal No. 1 A,

in the first reports (volume IV, page 410), but is not the equivalent of the Chinn's Branch bituminous coal, and of the others enumerated as belonging to No. 1 A.

Mr. Moore reports two beds between Coals 1 and 3, at Raccoon, Buffalo, and Laurel Furnaces. The same occurs at Iron Hills Furnace. The upper bed being thin, and limited in range, I have thought best to call it Coal 2 A. The Kibby coal, on Everman's Creek, is 28 inches thick, without parting. The opening by Mr. Elwood, on Everman's Creek, shows about two feet of coal. The entry of Dr. Jones, on Stand Branch of Barrett's Creek, presents a forty-three inch face, including six inches parting. On Mr. Lewis's place it is about the same. This coal has not been traced continuously southward across Carter and to the east, along the northward dip in Lawrence; but it has been noted at a number of points as a stain, or, where better exposed to view, as a thin coal. At Peach Orchard it is about two feet thick, and is known as the Barn Branch coal. The following is an analysis of the Kibby coal, which appears to be an average in that section:

Specific gravity	1.289
Moisture	4.10
Volatile combustible matter	34.60
Fixed carbon	55.25
Ash	4.775
Sulphur	1.414

The place of Coal No. 3 is generally well defined in Greenup and Carter, and in a part of Lawrence. It is found above drainage in a small portion of Boyd. It is the Coal No. 1 A of M. Lesquereux, as mentioned on Indian Creek, Chinn's Branch (Chinch Branch of his report), near old Steam Furnace, at Caroline Furnace, Hamer's coal at Amanda Furnace, on Bush Creek, and near the bed of Williams' Creek below Buena Vista Furnace. But to the westward it is higher up than the coal referred to No. 1 A. At Raccoon and Buffalo Furnaces it is sometimes called the Top-hill coal. (See sections 21 and 22, plate 7, and section 26, plate 8.) It is more commonly known as the Turkey Lick coal. Eastward from the localities named it is lower down than the coals referred to 1 A by M. Lesquereux, falling below drainage east of Hood's Creek and Little

Hood. (Section 50, plate 14; section 53, plate 15.) On the former stream it is shown near the bed of the creek for some miles above Bellefont Furnace. In the greater part of Carter it has about the same eastward dip, being near the bed of the creek at Mt. Savage Furnace (section 37, plate 10), and well up in the hill on Wolf Creek, and in the hills on Barrett's Creek, and on the Sinking Creeks. In the latter places it is a cannel coal, as appears from observations made in that section both by Mr. Moore and by myself. (Section 32, plate 9; sections 23 and 24, plate 7.) In Lawrence it follows the change in dip which has been noticed, being near the bed of Blaine at the ford near Mr. F. Carter's (section 10, plate 28), and about 180 feet above the bed of Brushy Creek at Mr. Holbrook's.

McHenry's coal, six miles south of Louisa, and the main Peach Orchard coal, which are referred to this bed, are 170 and 200 feet, respectively, above the bed of Big Sandy. (Sections 86 and 87, plate 23.) A coal imperfectly opened one half mile below the mouth of Rockcastle Creek, and 175 feet above Tug Fork, is probably the same bed. At Louisa it is probably from 60 to 70 feet below the bed of the river. In Greenup and Carter a block ore is generally found 30 to 35 feet above. In Lawrence this ore is not exposed; probably it might be found in the western part of the county. The rocks below Coal 3 to Coal 1 are variable in thickness. Between Coals 2 and 3 a block ore is sometimes found. These rocks are variable in character also, as will be seen from the sections given. The rocks above, for nearly 200 feet, are variable in character, but preserve a uniformity in thickness that is in marked contrast with those below; and this fact comes to have a very considerable importance from the facility which it secures in the tracing of beds both of coal and of ore. This will be seen as the beds above are taken up in this order; and the identification of Coal 3 will be made more certain, in most of this field, from its relation to overlying beds.

In thickness, Coal No. 3 varies with the different localities. At Raccoon, Buffalo, and Laurel Furnaces, it is pretty uniform-

ly three feet. At Pennsylvania Furnace it reaches five feet, with two partings. At Bellefont Furnace it is about three feet, with a thin parting. At Hunnewell (old Greenup Furnace), it is two and a half feet. At Mt. Savage it is not fully opened, but is probably thin. On Wolf Creek, in Carter, it is said to be three feet. On Blaine it is generally three feet. At Peach Orchard it is six feet, including three thin partings. McHenry's bank shows four feet four inches, including two thin partings. On plate III this coal is shown, as found at a number of points, with its immediate surroundings. It will be seen at once how unreliable an identification would be, based on resemblances, either in appearance or in details of the bed. The same is shown on other coals, in fewer representations on the same plate. Nor is the quality of the coal a satisfactory evidence of equivalency, as will be seen from the following table of analyses of Coal 3 by Dr. Peter and Mr. Talbutt:

	Specific gravity.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.
Raccoon, Greenup	1.335	4.54	35.58	49.79	10.05	3.77
Buffalo, Greenup	1.385	2.80	34.98	49.44	12.50	4.279
Laurel, Greenup	1.289	4.10	34.96	55.54	5.40	1.590
Pennsylvania Furnace, Greenup	1.300	3.20	36.00	53.14	7.06	2.264
McHenry's, Lawrence	1.316	4.60	35.70	53.28	6.42	1.080
Boggs' bank, Lawrence	1.317	2.50	38.78	53.10	5.57	2.466
Holbrook's, Lawrence	1.349	2.10	33.90	56.00	8.00	6.736
Peach Orchard, Lawrence	....	3.24	36.56	54.95	5.24	1.189
Carter Farm, near Grayson, Carter	1.389	3.00	36.20	49.24	11.56	1.381
Hunnewell, Greenup	1.333	3.20	32.90	53.80	10.10	1.043

Part of the variation shown by this table is doubtless owing to imperfect opening of some of the coals, which have been mined only along the outcrop, and which therefore show, to some extent, the effects of the broken and displaced surrounding rocks.

Coal No. 4 is less persistent than the previous. It is a cannel coal, with accompanying bituminous parts and is found 35 to 40 feet above Coal No. 3, or just above the block ore mentioned in connection with that coal, though that ore is commonly

wanting where Coal No. 4 has any considerable development. It is the Coal 1 B of Mr. Lesquereux, as described on the land of the Maysville Oil Company, and on Indian Creek, and around Greenup Furnace, now known as Hunnewell Furnace. It is traced eastward in Greenup and Boyd to Hood Creek (section 50, plate 14), though not opened to show either the thickness or the character of the coal. It is probable that only the bituminous part is present in this direction, though in the bed of Mile Branch, near Star Furnace, as shown by section 9, plate 29, by Mr. Moore, a considerable development of cannel coal is found. The cannel coal of Stinson Creek, and on the McGuire place, in Carter county, may be referred to this bed; though Mr. Moore, who has given more special attention to this part of the field, regards it as uncertain whether it is the equivalent of the Hunnewell cannel, or of the cannel coals of Barrett's Creek and the Sinking Creeks, which are referred to Coal No. 3. Coal No. 4 has not been found in Lawrence county, though at a number of points a bituminous slate occurs so nearly in its horizon that it might be regarded as its representative in this direction; section 5, plate 27, and section 9, plate 29, with section 33, plate 10, and section 41, plate 12, show the place of Coal No. 4, and its relation to other beds where it is present. The cannel coal of this bed is well known in the market as the Hunnewell cannel coal.

Coal No. 5 is from 30 to 50 feet higher up. It has its greatest development in Carter and Lawrence counties, where it is known as the Pennington coal, and the Cooksie Fork coal. It is mined at Buena Vista Furnace, in Boyd county, at a point a little way east of the furnace on Straight Creek. It is here considerably divided up by thin partings at the top of the bed, but shows a thickness of 38 to 40 inches of coal of good quality. On Brush Creek, it is shown with a blue ore, immediately above, in a thin bed of shales, which separates it from a thick sandstone above. It is also exposed, though not opened, close to the furnace. (Section 61, plate 14.) On East Fork, near Mr. Calvin's, it is exposed in the bank of the creek at the bridge. (Section 7, plate 25.) And at many points along the

eastern division of the Lexington and Big Sandy Railroad, this coal is shown near the grade. (Sections 54 and 56, plate 15; and sections 57, 58, and 59, plate 16.) But few openings have been made to show its thickness and value. As shown in some of the railroad cuts, it is not thick enough to work to advantage. It is probable that Coal No. 5 might be found at some points in the eastern parts of Greenup county, as it is shown to be present at Old Kentucky Steam Furnace, by a well marked coal stain (section 34, plate 10), but no openings of note have been made. In Carter and Lawrence counties this bed is greatly increased in thickness. Little has been done, however, to determine the real value of the bed. Section 39, plate 11; section 66, plate 18, show its position in the series. Plate 31 (Coal 5) shows the thickness and surroundings at several points chosen to illustrate the general character of the bed, where it has a considerable thickness. The place of Coal No. 5 is from 30 to 40 feet below the so-called limestone ore, where that is present. The horizontal range of the two beds seems to be about the same, though their boundaries do not coincide.

The quality of Coal No. 5 has not been fully determined from the difficulty of obtaining average samples; the bed not being worked, except at Buena Vista Furnace, where the following result was obtained by Dr. Peter and Mr. Talbutt:

Specific gravity	1.360
Moisture	3.20
Volatile combustible matter	32.30
Fixed carbon	53.00
Ash	11.50
Sulphur	1.999

The per cent. of ash is largely increased by including the upper thin layers, which might be rejected; the slaty portions of the bed interfere with the profitable mining of this coal, as shown by such openings as have been already made.

Coal No. 6 is found from 15 to 20 feet above the limestone ore. It is the Coal No. 1 B of Mr. Lesquereux, as reported near Catlettsburg, on Horse Branch, and on Catlett's Creek, and Coal No. 2, as described at Amanda Furnace and at Ashland. It is known as the Keys' Creek or the River Hill coal. Profile section No. 1 shows the position of this coal along the

Ohio. It has its greatest development in Boyd county, where it is mined at many points for local use and for shipment. Section 81, plate 22; section 77, plate 18; sections 61 and 62, plate 17; section 57, plate 16; sections 53 and 54, plate 15; sections 49, 51, 52, plate 14; and sections 1, 3, 4, 5, and 7, plate 25, give a good notion of the coal in Boyd. Detailed sections, plate 31, give the thickness and surroundings of this bed.

In Greenup this coal is shown at many points, but is less reliable both in thickness and quality. It occurs, but is not opened, at Old Steam Furnace. (Section 34, plate 10.) At Hunnewell Furnace it has been opened at several points. In Carter county the bed has still less development, though it is readily traced along with the outcrop of the limestone ore and the overlying ore. It is shown at Mt. Savage. (Section 45, plate 13, and in sections given in Mr. Moore's report.) At Willard it is shown in a railroad cut, and at a number of points west and south. (Section 1, plate 26, shows the place of Coal No. 6 on Little Fork, a short distance westward from Willard.) In Lawrence county this coal has been noted at several points, but it has been worked only at Louisa, along the Big Sandy river, near high-water mark. (Section 10, plate 28.) It is little more than two feet thick where opened at this point. The quality of Coal No. 6 is good, and even superior in some localities, especially in Boyd county, where it has its greatest thickness.

The following table is made up from analyses, by Dr. Peter and Mr. Talbutt, of average samples from Boyd county:

	Specific gravity.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.
Turkey-pen Hollow	1.359	3.40	32.30	55.40	8.90	1.230
Keys' Creek	1.279	2.94	32.50	56.70	7.74	1.972
Horse Branch .	1.315	2.70	36.70	52.60	8.00	1.711
Amanda Furnace .	1.335	4.04	33.60	53.34	9.00	1.318

Plate VII shows the variable character of this bed and its surroundings.

Coal No. 7 is normally from 40 to 45 feet above Coal No. 6, and 20 to 25 feet above the so-called yellow kidney ore, or the "black vein," as it is known by miners in some localities. This is Coal No. 2 of the old report, as observed at Kilgore's. It is now widely known as the Coalton coal, having been extensively mined originally at Coalton, as it is now at a number of points on the eastern division of the Lexington and Big Sandy Railroad, and also at Willard, on the Eastern Kentucky Railroad. This coal has already acquired a wide reputation as an iron-making coal. Its western outcrop is along the eastern border of Greenup county, and across Carter, a few miles west of Mt. Savage Furnace; and thence along the line of hills east of Little Fork and of Little Sandy. The low hills of the "Flat Woods" country do not include this coal, there being very little eastward dip across this belt, and the hills being barely high enough to include the limestone ore. From a little east of Ashland Coal No. 7 rapidly falls to the base of the hills that skirt the Big Sandy. (See first profile section.) The thickening of the sandstone above Coal No. 6, near the Big Sandy, on Keys' and Catlett's Creeks, is accompanied by a corresponding decrease in the thickness of Coal No. 7, and the distance between the coals is increased to 55 feet or more, the sandstone entirely replacing the shales below, and even the coal itself in places. At Catlettsburg it is shown as a stain evidently of a thin coal, about 60 feet above Coal No. 6, which is opened below high-water. (Section 81, plate 22.) Near the mouth of Chadwick's Creek, however, it has a thickness of three feet without partings. It was formerly worked at Clinton Furnace, about 40 feet above the bed of the creek. (Coal No. 1 C, of first reports.) It is opened near Cannonsburg in several places, and it shows a good thickness in the road from Cannonsburg to Coalton, near the tunnel. Along the railroad southward to Rush Station it is from 80 to 100 feet above grade. (Sections 57, 58, and 59, plate 16.) On East Fork, at the mouth of Old Trace, it is from 40 to 50 feet above the bed of the Fork. A coal that appears to be the same is shown in the bed of Ellington's Bear Creek, near the school-house and

church. At the school-house, above *Mr. Kouns's*, it is in the bed of East Fork. On Four-mile Creek it is opened at *Mr. McBrayer's*. Further southward it is below the waters of East Fork. It is found on all the Buena Vista lands, rising towards the tops of the hills on the west side. (Section 51, plate 14.)

On the Hunnewell side of the divide between the waters of East Fork and of the Little Sandy, Coal No. 7 is too high up to be profitably mined at present. Its place is shown by a stain in the road leading down from the ridge to Cannel Branch of Cane Creek, and at the head of Cane Creek it is opened. (Section 36, plate 10.) It is present in most of the Mount Savage Furnace lands, following the eastern dip, which brings it below drainage on the East Fork side of the main ridge. (Section 27, plate 8; section 65, plate 18.) (See also sections in Mr. Moore's report.) At Willard Coal No. 7 is about 90 feet above Dry Fork, rising rapidly to the tops of the hills westward and southward, from near the mouth of Caney Fork, where it is lowest; while northward it rises less abruptly, and to the eastward it rises slightly for some distance, probably to the divide between Lost Fork and East Fork. In Lawrence county Coal No. 7 is below drainage along the northern part, and it has not been opened, except near Louisa (section 2, plate 28), and perhaps on the farm of Mr. Burchett, on Muddy Branch of Blaine, where a coal not readily distinguished from Coal No. 8 has been mined for local use. In the southeast part of Lawrence county the coals above Coal No. 3 have not been fully identified, the work not being completed in this section, partly from a want of time, and partly from the fact that in this direction changes in the character of the rocks occur, which make it desirable to study this section in connection with the adjoining counties to the south and southwest. The thickness of Coal No. 7, where it has been identified, is from three and a half to six feet, in two or three parts of about two feet each; the upper part disappearing when the bed is less than six feet. The partings are remarkably regular, and have a thickness of from one to three inches each. The Big Sandy valley fur-

nishes an exception to the general character of the bed as found elsewhere. Plate 31 shows the general character of the bed at some of those points where it is best known. Coal No. 7 is more widely known as an iron-making coal than any other bed in Eastern Kentucky, being used without coking with marked success. Mr. Moore has discussed the metallurgical qualities of this coal in his report.

Above Coal No. 7 from 20 to 30 feet is the red kidney ore, as it is commonly designated. This ore and the ore below, generally accompany this coal. From 40 to 55 feet above Coal No. 7 is Coal No. 8, the bed next below the Mahoning sandstone of Owen. It has its best development apparently on Garner Creek. It is commonly known, however, as the Hatcher coal. It is present in a field very nearly coinciding with that of Coal No. 7 in its western outcrop, but it is found above drainage over a large territory to the eastward, being above the bed of most of the main creeks. On East Fork, from the mouth of Jack's Fork to near Mr. Webb's; on Bolt's Fork, and on Long Branch of Blaine, it is below drainage. It is sometimes wanting entirely in parts of this field. At Coalton it was opened, and showed, as reported, between three and four feet. On Garner Creek, and near the head of Lost Fork, near Willard, it shows nearly four feet of coal without parting. At Mr. Webb's, on East Fork, a coal, part cannel, occurs in the bed of the creek in such stratigraphical relations as to be referred to Coal No. 8. (Section 65, plate 18.) Along the Big Sandy it is seen at a number of points above and below high water. On the West Virginia side it is mined at a number of points above the mouth of Bear Creek; and the openings along Tug Fork, near Louisa, appear to be in this bed. Coal No. 8 is generally inferior in quality to Coal No. 7, and has therefore been opened in but few places. In a part of Boyd county a so-called "bastard limestone ore" occurs about 20 feet above, and also kidney ores still above. Generally, however, an impure yellowish limestone follows Coal No. 8, at a short distance above, succeeded by a coarse sandstone or a conglomerate sandstone. Section 60, plate 16; sections 62,

63, plate 17; sections 69, 71, plate 19, also furnish examples of this. See also sections on plates 26, 28, and 30.

Coal No. 9 is from 40 to 50 feet higher. It is not worked except for local use, but it is present over such an *extent* of country as to entitle it to a place in the list of coals of this region. It is opened at Mr. William Davis's, on East Fork, in the hill opposite the mouth of Garner Creek. It shows at the head of Lost Fork and of Bell's Trace, near Willard; is seen occasionally eastward, on the waters of Cat Fork of Blaine. Sections 69 and 71, plate 19; section 3, plate 30; section 8, plate 26; and section 4, plate 28, show this coal.

Coal No. 10 is known over less territory, and is opened in only one place, so far as I can learn, though a coal stain has been noted at a number of points, showing that it is more than a local deposit. On Cannel or Rock-house Branch of Jordan's Fork, where it is opened, it is a cannel coal of good quality, two and a half feet in thickness, immediately under a calcareous rock, the second fossiliferous limestone. (See section No. 1.)

Coal No. 11 is also little known, and opened only at one point near Col. Bolt's, on East Fork. (Section 8, plate 28.) It is known as Bolt's coal, and has a thickness of three and a half feet. It is about 40 feet above the second fossil limestone. (See general section, plate 1.)

Still another coal is shown near the top of the hills between the Falls of Blaine and Louisa, but little is known of its thickness or value.

Having given an account of the coals, and incidentally of the ores that occur in this part of Eastern Kentucky, and such an account of their range as is shown by openings already made, it seems desirable to present the whole subject in such a way as to give the number of coals and of ores that are likely to occur in each considerable valley, and to point out as well as may be the place of each bed. This will place, in the most available form, the facts, which it is the purpose of the survey to collect, at the disposal of those who are most immediately interested, viz: the owners of the land. At the same time the geology of this field may be presented more in detail

for the student, and for those who are interested in mineral lands generally. If there were no considerable variations in the rock beds as they extend across the country, and as they appear in the series from the base upwards, there would be little need of a more detailed account than has already been given. But the changes which occur in the rocks of the same geological level—changes which affect the distribution of the coals and ores—make it impossible to represent by sections and general statements the range of beds so distinctly as to present the facts in the most useful form for each locality. In the sections which accompany this report (excepting the profile sections), it is intended to present such features only as have been seen, though there might be good reason for supposing that other features, known to hold a somewhat constant relation to those observed, were covered by the soil which hides a large proportion of the rocks of most hills. In offering suggestions as to what may reasonably be expected to occur in a particular valley or hill, it is necessary to go beyond this, and to consider the probability of the occurrence of beds known to be present elsewhere at the same geological level. It will be well, therefore, to keep in mind the distinction between what is known to exist and what may be looked for with a reasonable hope of success; for, with all the knowledge that can be brought to bear on a question of probability, there is room for error in the conclusions reached, and this fact would be a sufficient excuse for presenting simply that which is known, if it were not the purpose of the survey to aid in developing the unknown resources of the country, as well as to call attention to what is already exposed to view. The forces and the conditions which gave rise to the carboniferous rocks were not so uniform, but that the development of a coal region has in it something of the nature of an experiment; and the part that science must take in the matter is to point out, from what is known, the line of experiment most likely to lead to good results. This it can do for the coal measure, by showing, from the character and the stratification of the rocks, at what level certain coals and ores may be found. The thickness or value

of the beds may, to some extent, be inferred from its character, where known; but only actual working of the bed can fully determine such questions. But while in general a good deal of useless expenditure, both of time and money, would be saved by such directions as will be given here, it is possible that local beds of great value may have been overlooked in so rapid a survey as it has been necessary to make of this large field.*

The general section (plate 1) presents, in one view, all of the most important beds of coal and of iron ore, as also of limestone and of fire-clay, as they occur in different parts of this field. The profile sections show most of these beds with their probable range, east and west. From these sections it is easy to determine, in a general way, what geological horizons are included in the hills along the different belts of country from west to east. For instance, profile section No. II shows that it would be useless to look for Coal No. 6, or the ferriferous limestone and ore just below it, west of the Little Sandy river, along this line, and that it would be equally useless to look for Coal No. 1 above the drainage, for any considerable distance east of the Little Sandy. The reasons for this are sufficiently apparent from the section itself. Profile sections I, II, and III, together with those sections which are based on tide-level, complete this general representation of the range of beds in this field. It remains to call attention to the special geological features of different localities as they affect the question of distribution of the coals and iron ores.

For convenience of reference to the map, the prominent streams will be used to indicate locality.

On Indian Run the Waverly formation rises to a height of about 500 feet above low water in the Ohio. Neither coal, nor ore in paying quantity, will be found in it. Some compensation for this is found in the building stone that occurs in the Waverly formation, and in the nearness to river transportation. A few feet above the top of the Waverly, as marked by a flinty

*Observations which come within the range of the report cover a territory something more than 1,000 square miles in extent.

bed of rock, occurs the bed of non-plastic fire-clay, which is shown at many points along the western part of the coal field. A general description of this bed has been given on a previous page. Below this bed, and at the top of the flinty rock, there are slight indications of the lower "limestone ore." As this cherty rock is doubtless the representative of the sub-carboniferous limestone, it is not unlikely that the ore which rests upon that formation may extend to this part of the field; but the indications do not warrant the assertion that it would be found in paying quantities at this point. About 40 feet above the fire-clay Coal No. 1 occurs, as shown in a well near the top of the hill. The *thinness* of this coal at this point will make it available for local use only. All of these beds rise towards the west, and to the eastward would be found lower down. The average dip to the eastward is about 45 feet per mile from the head of Indian Run. The character of the rocks between the fire-clay and Coal No. 1 is imperfectly shown, but from what is known of the rocks of this horizon, it may be assumed that no other beds of considerable value occur in this section.

White Oak Creek heads back of Springville, the river hills forming one side of the White Oak valley. The river hills at Springville show a continuous section of Waverly rock to near the top. (Section 5, plate 3.) The fire-clay bed is found covered by no more than ten feet of rock and soil. The dip of the rocks to the eastward brings this bed lower in the hill toward the Tygert's Creek valley, so that, though the hills are lower, yet above the fire-clay towards the mouth of White Oak there is sufficient thickness of overlying rock to include No. 1 Coal. Southward across the White Oak valley, an exceptional dip of the rocks also brings those beds lower down in the hills; but with the addition of a block ore, which sometimes occurs above Coal No. 1, no other beds of importance are likely to occur. The top of the Waverly formation is easily recognized from the occurrence of limestone or flinty rock, or, in the absence of both, by a change from greenish fine-grained sandstone or shale to dark shale or to a coarse

grey sandstone. The readiest way to find this bed is to measure upward from the Waverly the normal distance, as shown in sections given, nearest the point where it is desired to develop them. Some variations in thickness will be found, but these variations will be readily detected and indications of the beds found when they are present.

The exceptional dip mentioned in this region deserves a passing notice. In general the rocks of a given geological level rise towards the south, as noticed before, but the elevation* of the Waverly rocks, as shown in the hills back of Springville, presents a marked exception to the general rule, and this exception continues eastward to the river hills above the lime-kilns. The top of the Waverly at the lime-kilns is fully 100 feet higher than at Bennett's Mills. (Section 9, plate 4, and section 17, plate 6.) The top of the Waverly again rises to the southward, from Bennett's Mills. It will be seen by reference to the map that this region of southward dip is included in the bend of the Ohio river. It has its limit on the south, near a line which might be drawn from near the mouth of Smith's Branch, to a point a few miles south of Indian Run, including most of the Shultz Creek valley. Probably the dip is not uniform over the area included in these boundaries.

The hills which form the valley of Shultz Creek rise to the height of from 350 to 450 feet above the creek. The following section of the hill, on the south side of the valley, near the mouth of the creek, shows an ore which may have more than a local distribution:

Top of hill above creek	440	feet.
Covered slope	15	"
Block ore	6	inches.
Shale	5	feet.
Conglomerate sandstone	20	"
Shale	3	"
Cherty limestone	?	
Waverly sandstone and shale	395	"

*It is probable that the change in dip is in consequence of an upheaval of the Waverly rocks, rather than of a thickening of those rocks. Mr. Andrews has remarked inequalities in the surface of the Waverly formation of Ohio, which would give rise to nearly as great a change of inclination of the surface of the Waverly. But in the region in question the overlying rocks conform very nearly with the top of the Waverly in stratification, and the occurrence of slight faults, such as noted near the mouth of Linn Branch, tend to make probable the former explanation.

On the Plum Fork side, on the place of Judge Fullerton, this ore is shown, and also another, 30 feet higher up—the well-known lower block ore of this belt of country.

Top of hill.	
Covered slope	15 feet.
Block ore.	
Covered space	30 "
Block ore shown in well.	
Shale	5 "
Conglomerate sandstone.	

The fire-clay is wanting on the south side of the valley, where the conglomerate sandstone has a considerable development. On the opposite side the conglomerate is not so prominent, and the fire-clay is said to be present. Near the head of the valley the following section is shown on the right hand side:

Top of hill above creek at Mr. Aldrich's . . .	340 feet.
Covered slope.	10 "
Block ore (lower block).	
Covered space.	40 "
Limestone, cherty at top	8 "
Waverly sandstone and shale to bed of creek	280 "

The fire-clay would probably be found all along the ridge. Coal No. 1 has not been opened in this region, but it would doubtless be found, wherever the hills are high enough to include it, in sufficient thickness to supply local demands. The conglomerate sandstone in this region is a coarse ferruginous sandstone simply. It is well shown at Mr. Fullerton's, where it forms an escarpment around the hill, and at the head of Petre Cave Branch, where a small cave is formed by the overhanging rocks. Towards the head of the valley this rock is less prominent, so that it is not noticed as affecting the topography of the country. Plum Fork valley is nearly the center of the geological basin formed by the uplift that has been described. The conglomerate sandstone is present in this valley, resting in places immediately on the Waverly, and excluding the fire-clay, as in the section on Judge Fullerton's place given above. On Beechy Creek the conglomerate appears to have lost its importance, and probably the fire-clay, Coal No. 1, and the lower block ore would be found in this valley.

At the mouth of Brushy Creek the coal measures begin at about 150 feet above the bottom land of Tygert's Creek valley. At the New Hampshire Furnace it is also about 150 feet above the creek; the dip to the eastward being about the same as the fall of the stream. The lower limestone ore is found towards the head of the valley; its limit eastward is not clearly made out, but it is not likely to occur in paying quantity near the main Tygert Creek valley. The following section, together with section 11, plate 4, and section 41, plate 12, indicates what ores are likely to be found in this valley:

Top of hill north of furnace.	
Covered slope.	15 feet.
Block ore.	
Covered space.	50 "
Limestone ore.	
Waverly to hearth of furnace	100 "

No coal is shown. It is likely, however, that a thin coal would be found a short distance below the lower block ore. The limestone ore is not present throughout, but it is mined at many points for Kenton Furnace. The fire-clay bed was not seen in this valley, but there are no geological features that would lead to the conclusion that it is not present.

The hills near the head of Big White Oak Creek are high enough to include the lower block ore only; towards the mouth of the creek the hills include more of the carboniferous rocks. Section 12, plate 4, and section 2, plate 29, and sections given in the report of Mr. Moore, show the position of the ores of this valley. It will be noticed that in Powder-mill Hollow the fire-clay is shown between the limestone (sub. carb.) and the coarse sandstone (cong. S. S.) above, while at the Shover drift, where the sandstone is considerably increased in thickness, it is entirely wanting. Coal No. 1 is from one to two feet in thickness, and is mined for local use on the Kenton Furnace lands. It is valuable for blacksmithing purposes. An analysis made by Dr. Peter and Mr. Talbutt, from sample taken from stock pile, shows the following properties:

Moisture	4.82
Volatile combustible matter	32.90
Fixed carbon	55.18
Ash	7.10
Sulphur	1.407

The coal opened at Thompson's bank appears to be lower than Coal No. 1, though it is doubtless above the fire-clay, and may be found to be the equivalent, in this locality, of No. 1. The section at Thompson's bank is interesting as showing a band of somewhat silicious limestone, which has been noted at a number of points, and which is probably the equivalent of the Putnam Hill limestone of the corresponding belt of country in Ohio.

Top of high point.		
Covered slope	40	feet.
Blue silicious limestone	2	"
Covered (sandstone and shales)	95	"
Rough block ore.		
Shales with sandstone at top	15	"
Block ore (lower block).		
Shales mostly	30	"
Sandstone	5	"
Coal	1½	"
Shales, including fire-clay	20	"
Limestone ore.		
Waverly to bed of White Oak Creek, about	175	"

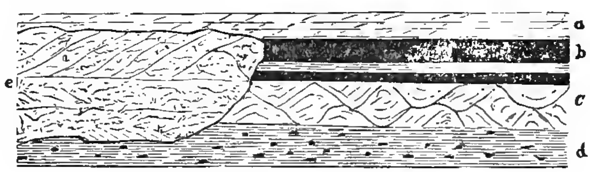
The thickening of the limestone, as shown southward from Brushy Creek, continues across the heads of Little White Oak, Big Lost, and Leatherwood Creeks. Few openings have been made on these creeks. The sections given on the Kenton Furnace lands would doubtless be found a sufficient guide for developing the ore of the region drained by these creeks. Section 18, plate 6, near the mouth of Big Lost Creek, shows only the limestone ore; but the hills are high enough to include all the ores shown in the sections near Kenton Furnace.

On Three Prong little is shown beyond the general geological features. The sections on the Boone Furnace lands, together with those referred to in the preceding paragraph, will serve to point out the place of the beds that are likely to occur in this valley.

On Grassy Creek the ore beds have been quite extensively developed. The Waverly rocks rise to a height of nearly 300 feet above the creek at Boone Furnace, and the carboniferous rocks are separated from them by sub-carboniferous limestone reaching in places a thickness of 90 feet. Near the furnace the hills are high enough to include the beds shown in the following section, taken south of the furnace:

Top of hill.	
Covered slope	35 feet.
Block ore.	
Covered space	50 "
Limestone ore.	
Limestone	80 "
Waverly sandstone, nearly	300 "

To the westward only the limestone ore is left, as in section 7, plate B, at Old Orchard drift. In this section a thin coal is shown, which is a sub-conglomerate coal, as indicated by its position. An instructive feature is shown at one point, where the coal is abruptly replaced by a coarse sandstone. The accompanying cut, which represents this feature, will serve to explain what may be expected to occur in other beds, both of coal and of ore.



a. Shaly sandstone.
b. Coal with clay parting.
c. Fire-clay, non-plastic.
d. Dark shales, with nodules of iron ore.
e. Coarse S. S., showing cross-bedding.

The interruption of a bed by the interposition of deposits of sandstone or of other rock, has frequently proved an annoying feature in mining. Generally the interruption may be regarded as a local feature, limited to a narrow belt, along which the character of the deposit was modified by local currents. Sometimes, as reported in the mines of the Maysville Oil Company, near Riverton and Greenup, a thickness of only a few feet of rock is interposed, and the bed continues with slight interruption. Coal No. 1 is not shown in the valley of Grassy Creek, so far as I can learn. There appears to be no special geological reason for the absence of this bed, and it is likely that it will be found at its proper level. Southward from Boone Furnace the limestone formation continues to increase in thickness, and also the conglomerate becomes more prominent, and rests in places immediately on the limestone, cutting out both the fire-clay and the limestone ore. This is the case at Sel-

lard's Bank, on the waters of Buffalo Creek, opposite Boone Furnace. At the roadside, about 400 yards above Mr. Frailer's, on Grassy, below the furnace, a highly fossiliferous band of sandstone is found in fragments which have fallen from the cliff above. At no other point have fossils been discovered in this Waverly rock in so great numbers both in individuals and species. The Waverly formation in this region is less shaly than near the Ohio, and would furnish superior building stone at a number of levels.

Buffalo Creek drains a country very much like that drained by Grassy Creek, which is one of its main branches. There is greater thickness of limestone and of conglomerate, as shown in section 14, plate D, and in a section on Smith's Branch (report of Mr. Moore), which gives the following thickness:

Top of hill.	
Covered slope	60 feet.
Block ore.	
Covered space	60 "
Conglomerate sandstone	90 "
Limestone ore.	
Limestone	105 "
Waverly.	

The thickening of these formations is strongly marked in the topography of the country. The effect which it has on the distribution of the ores, which are shown in the section at Kenton and Boone, is not clearly made out; but the rocks above the thickened conglomerate masses appear to be identical with those which rise above the thin conglomerate formation at these places, and it is probable that the block ores which follow in those rocks, with the coal sometimes included, are the beds that will be found in the tops of the hills in this valley. Towards the mouth of the creek the hills may include beds higher up, the dip of the rocks to the eastward giving a greater thickness of the rocks of the coal measures. The geology of Cave Branch is similar to that of the head of Buffalo Creek. The well-known Carter Caves and the Natural Bridges are formed in the limestone near the bed of the branch, or about seventy-five feet above Tygert's Creek; the conglomerate rises 90 feet above the limestone, and the hills,

reaching only a moderate height, are capped by the shale series above the conglomerate; the highest probably including rocks as high as Coal No. 2, though no trace of the bed has been found in this locality. The limestone ore is doubtless present over some of this territory, though at some points the conglomerate is observed to rest immediately on the limestone ore, as in section 20, plate 6. The topography which arises from the rocks shown by this section adds very much to the picturesqueness of the scenery around the caves.

Smoky Creek and Trough Camp Creek cut through the same formation as Cave Branch and the head of Buffalo. A section, as shown in the road between Trough Camp and Smoky Creeks, gives the position of the limestone and the limestone ore:

Sandstone, with shale at base.	
Limestone ore.	
Limestone (sub-carb.)	150 feet.
Waverly to bed of creek (Trough Camp)	35 "

The hills here include 100 to 150 feet of the rocks above the conglomerate, or to the place of Coal No. 2. (See general section.)

The section at Olive Hill (section 15, plate 5), and section 8, plate 3, and section 4, plate 2, with section of east side of Garvin's Hill, Mr. Moore's report, gives a good notion of the economic geology of the country drained by the forks of Tygert's Creek. Towards the head of North Fork and of Soldier's Fork, the coal measures are carried near to the tops of the hills, as in all the valleys of the main creeks west of Tygert's Creek. Very little has been done to open the ore or coal beds in this region. On Garvin's Hill several ores have been imperfectly opened, and near Olive Hill the sub-conglomerate coal is worked for local use. The hills east of the Tygert's Creek valley, and nearly opposite the mouth of Soldier's Fork, show the following section:

Divide between Tygert's Creek and Big Sinking.	
Covered slope	50 feet.
Coal thickness not shown.	
Coarse sandstone and covered space	60 "
Limestone (sub-carb.)	60 "
Waverly to bed of creek	55 "

The coal shown is above the conglomerate, and is probably Coal No. 1. Both the limestone and the conglomerate are less prominent than at Olive Hill, or than farther south. To the westward, from a line starting at Boone Furnace, touching Olive Hill, and extending to Big Falls Branch of Big Sinking, both formations rapidly lose their importance. This is well shown along the old Lexington and Big Sandy Turnpike. At the bridge below Olive Hill 90 feet of limestone is shown, and a considerable thickness of conglomerate sandstone. On the west side of Garvin's Hill only 25 feet of the former, and 10 to 15 feet of the latter, is found. This will explain the occurrence of the coal-measure rocks above the conglomerate, west of the waters of Tygert's Creek, along the border of Rowan and Lewis counties. It will be noticed that Tygert's Creek flows along the line of the greatest thickness of the limestone and conglomerate, fed almost exclusively by branches from the west, which have cut their way through these formations, and have their beds in the Waverly rocks. The branches from the east are all short, and flow rapidly across the slightly upturned edge of these formations from the coal-measure rocks above. From 100 feet to 200 feet of these latter rocks will be found along the eastern side of the Tygert's Creek valley, down to the bend in which is situated the Iron Hills Furnace property. Here the eastward sweep of the creek, with the thinning out of the limestone and conglomerate sandstone, give to the rocks above a thickness of more than 300 feet in some of the higher hills. A section of the high hill, to the south of Iron Hills Furnace, about two miles (known as "Potato Hill"), shows the following:

Top of hill.	
Covered slope	40 feet.
Block ore ("Potato Hill ore.")	
Covered slope	65 "
Block ore.	
Covered space	55 "
Coal, thickness not shown.	
Sandstone and shales	65 "
Thin coal.	
Covered to limestone, about	150 "

Section 19, plate 6, and the following of Smith's Hill, and on Tygert's Creek, one mile south of furnace, show the geological position of most of the beds of this region.

SMITH'S HILL.

Top of hill	
Covered slope	40 feet.
Block ore ("Crown ore.")	
Shales and sandstone	21 "
Block ore ("German ore.")	
Sandstone and shales	32 "
Lambert ore.	
Covered to limestone	75 "

TYGERT'S CREEK, ONE MILE ABOVE FURNACE.

Block ore.	
Shales	5 feet.
Coarse sandstone (Cong. S. S.)	45 "
Shales	10 "
Ore.	
Shales	15 "
"Blue ore."	
Limestone	35 "
Waverly formation.	

Coal No. 1 is opened in the hill back of the furnace, showing only about a foot of good coal. Some of the beds of ore are local, as will be seen by comparison with sections at the nearest furnaces, as also by comparison of one section with another, as the Lambert ore section and the section one mile south of furnaces. The Lambert ore shows a thickening which makes it the most important bed in this locality. The coals shown in the section of Potato Hill are Nos. 2 and 2 A. No. 3 Coal would probably be found from 30 to 40 feet below the "Potato Hill" ore, though no stain has been observed, showing its exact position or its extension to this part of the field.

Further to the north the thickness of the coal-bearing rocks, in the hills forming the east side of Tygert's Creek valley, varies from 200 feet to 300 feet, including, with some local variations, the beds shown in the general sections above the conglomerate formation. The conglomerate sandstone and the limestone are present in reduced thickness for some distance northward of the Iron Hills region. On Hood Run the limestone is reported by Mr. Moore; thickness not fully determined. No limestone is shown on Rock Lick Branch, above

Liberty. Section 17, plate 6, near Bennett's Mills, shows no limestone. In the former place a coarse sandstone probably represents the conglomerate, and the coarse sandstone shown in section 17 may be the same, giving the thin coal the place of No. 1 rather than of the sub-conglomerate coal of other localities. Section 7, plate 4, near the Ohio, includes less of the coal-measure rocks, for reasons which have been given. Coal No. 1 would probably be found here as a thin bed. The limestone ore is shown on Mr. Ratcliff's place; but as no attempt has been made to develop the ores in this section, no very definite information has been obtained as to the extent of the deposit. The presence of the sub-carboniferous limestone is of itself a sufficient reason, however, for presuming that the ore is not wanting in this region.

The branches which empty into the Ohio between the mouth of Tygert's Creek and the Little Sandy river are comparatively short. They all rise in the coal-bearing rocks and flow down, across the edge of the rocks of that formation, and out to the river, in the Waverly sandstone and shale. The river hills here appear to be more barren of both coal and ore than the hills of the same geological level farther back. Whether this is really true, to the extent that appears from what is now known, may be regarded as doubtful. Section 25, plate G., shows most of the face of the hill at the mouth of Little Sandy river, without indication of either coal or ore above Coal No. 2, which is thin, as shown here. But it is not unlikely that Coal No. 3 would be found at the proper level here and in all the hills that include the rocks of this level, or that rise 300 feet above the line which marks the top of the Waverly, the limestone being mostly absent, and the conglomerate formation having only a slight representation along these hills. The band of coarse sandstone shown in the tops of the hills, between Coal Branch and Smith's Branch, appear to be the same as that which frequently rises above Coal No. 3. In the profile section, the block ore is represented as falling below this sandstone; but this is an error, as the block ore is

usually wanting where this thick sandstone is present. Vol. 4, page 373, report of 1861, mentions this sandstone on Whetstone Creek, near Mr. Steward's, but it is there mistaken for the Mahoning sandstone. The coal just below was therefore wrongly referred. This is doubtless Coal No. 3, as numbered in this report, and not the equivalent of the Stinson Hill cannel. The thin coal at the base of section 25, near the mouth of Little Sandy, is referred to the sub-conglomerate series, as well as the Coal Branch Coal near Mr. Richards' house. The reason for this is seen from its relation to the non-plastic fire-clay bed, which is clearly a sub-conglomerate bed. In this region, therefore, the sub-conglomerate shales unite with the shales above the conglomerate, to form one series, having a thickness of nearly 60 feet. At many points, however, a coarse ferruginous sandstone marks the line of separation, as near the head of Coal Branch, where the coarse sandstone, which forms a large rock house, becomes locally prominent. Smith's Branch and Gray's Branch have nearly the same geological features as Coal Branch, except that the rise of the top of the Waverly reduces the thickness of the coal-bearing rocks in that direction, as shown by profile section No. 1.

Comparatively little has been done to develop the mineral resources of Whetstone Creek, and the same may be said, with some qualifications, of Allcorn Creek. On Whetstone Creek several coal beds were formerly opened near Mr. Steward's, as described by M. Lesquereux. They are doubtless Nos. 1, 2, and 3, as numbered in this report. The ores of this region will be readily found from their relation to these coals, as shown in the sections on Raccoon Creek, where the location of the Raccoon Furnace has led to the development of the ores more especially, but where the coals are also opened sufficiently to show the geological position of the beds and their relations to the ore. Sections 21, plate 7, shows the height above drainage of some of these beds. From the base of the section to the Waverly formation is probably not more than ten to fifteen feet, as I am informed by Mr. Moore, who has given more especial attention to this region. This would

place the coal in the bed of the creek* nearly in the position of the Coal Branch coal, which is referred to the sub-conglomerate formation. The absence of the fire-clay bed and other well-known evidences of position in the series, makes this somewhat doubtful, however, and its relation to the beds above make it more probable that it is No. 1 Coal.

Sections at different points, as given in report of Mr. Moore, show the relative positions of the beds found in this section, nearly as follows:

Sandstone, near top of hill opposite furnace	5 to 10	feet.
Shale	3 to 4	"
Block ore (main block).		
Sandstone mostly	35	"
Coal No. 3, in two parts	3	"
Sandstone with shales at top and bottom	70	"
Hearth rock	4	"
Thin coal and shales (No. 2 A). . . .	2	"
"Grey ore."		
Sandstone and shale	8	"
Coal (No. 2). . . .	2	"
Shales and sandstone	30	"
Lower block ore.		
Shales	35	"
Coal in bed of creek above furnace	2½	"
Shales	10	"

The grey ore is a local bed, and would not be found over the whole area in question. The second coal has been mined for local use here, and would probably extend into the other valleys. Coal No. 3 and the main block ore are constant, and would be found wherever the hills include the rocks of this level, or form a line considerably to the west of Raccoon Furnace, eastward, over the whole region in question; though the supposition that the coals near the Ohio fall off in thickness may prove true. The sandstone above the main block ore, at some points, is filled with plant impressions, representatives of the Lepidodendron and of the Calamites principally. The shale above this ore has, at some points, abundant representations of ferns and other plant forms. A thin coal is also in-

*This bed has been recently opened, and about thirty inches of coal is shown, instead of about one foot, as exposed by the creek. The following analysis, made by Dr. Peter and Mr. Talbutt, is of this coal:

Specific gravity. . . .	1.409
Moisture	4.10
Volatile combustible matter. . . .	28.90
Fixed carbon. . . .	49.60
Ash	17.40
Sulphur. . . .	.668

cluded at one point where the plant impressions are most abundant.

The section in the valley of Clay Lick Creek is similar to that at Raccoon Furnace. There is, however, a marked difference in the whole thickness of the corresponding rocks, especially on the south side and near the Little Sandy. Section 26, plate G, shows this. A general section of this region would include a coal (thickness not fairly shown) 70 feet below Coal No. 3, and a local bed of ore is shown near the furnace, 50 feet above the "Lower Block ore."

A general section for this region is as follows:

Covered slope.		
Sandstone (hearth rock)	5	feet.
Shale	3	"
"Top-hill" or main block ore.		
Sandstone and shale	35	"
Coal No. 3	3	"
Sandstone and shale	30	"
Rough block ore.		
Sandstone and shales	40	"
Coal No. 2 A; thickness not shown.		
Sandstone and shales	65	"
Grey ore; local so far as known.		
Shales and sandstone	50	"
Lower block ore.		
Shales	45	"
Coal No. 1 in bed of creek below furnace.		

A greater variation from this general section will be found than in the valley of Raccoon Creek.

The valley of Old Town Creek shows a continuation, with some variations, of the geological features already described in this belt of country. The North Fork has its bed in the base of the coal-bearing rocks for nearly its whole length; but as the fall of the stream is less than the dip of the rock, the sub-carboniferous limestone is exposed near the head of this fork, with the limestone ore and the bed of non-plastic fire-clay. The ore is not shown in its usual thickness, as exposed where the limestone is quarried for use at the furnaces. The fire-clay appears at its usual thickness and in its usual place at the base of the coal measure, as in the following section:

Fire-clay, not seen directly over the limestone	4 to 5	feet.
Shales, probably	10	"
Coal stain.		
Shales	2	"
Greenish, irregularly-bedded limestone	6	"
Grey limestone	4	"
Waverly.		

Section 22, plate 7, near Laurel Furnace, with the general section for Buffalo Furnace, gives a good notion of the economic geology of both forks of Old Town Creek. Some openings on North Fork, at various points, show nearly all the constant beds, as given in the general sections for Buffalo Furnace, with the addition of clay-stone ore, as exposed in dark shales near the bed of the creek below the Buffalo Furnace road—a local deposit in the dark shales just above the limestone. At a point a little way up the creek a coarse sandstone occupies the same level. This is probably the representative of the conglomerate sandstone. The sandstone above the lower block ore is characterized by a profusion of plant impressions similar to those noted above the main block at Raccoon Furnace. The ore of the Buck Smith's bank is the upper or main block ore. Coal No. 3 is not opened, but would doubtless be found at the usual distance below this ore. Coal No 1 is not shown to be present in any considerable thickness above the fork of the creek. Near the Little Sandy it is present in workable thickness, as shown at the Hanna bank, just below the mouth of Old Town Creek. It would be found, if present, above the bed of North Fork, for the greater part of its length, as also for some distance on the main creek. What the exact place of the bed is has not been satisfactorily made out. The lower block ore would probably offer the best indication of its location by its quite constant occurrence 40 to 50 feet above this bed. Near Laurel Furnace the economic geology is well shown by section 22. Less has been done to develop the coals than the ores; as is true for all this belt of country. The furnaces being constructed originally for charcoal, and an abundance of timber being found, there is little inducement as yet to incur the expense of opening and testing mineral coals. Little else can be done, therefore, than to point out the place of such beds as are known to hold a somewhat constant place in the series. The sections given by Mr. Moore in his report, with those already given, will seem to indicate the place of these beds, together with such local beds as have been developed.

Lost Creek flows for the greater part of its course in a coarse sandstone—the conglomerate sandstone, which shows at the base of section 22. As the geological features of this valley differ little from those of Old Town Creek, the geological section for that valley would doubtless be repeated here with such variations as usually occur within a limited field. The same is true of Crane Creek, which is separated from Lost Creek by a narrow ridge only. Near the mouth of Lost Creek the conglomerate sandstone rises in cliffs which are characteristic of this formation.

On Everman's Creek the conglomerate sandstone is prominent at many points as a coarse ferruginous sandstone, which will be recognized at once, and can be made serviceable in making out the equivalency of the beds in the hills above. At some points this formation is entirely wanting, or so changed in character as not to be recognized. The sub-conglomerate shales are present, however, as shown by the occurrence of the fire-clay bed, as exposed above the forks of the creek on the Middle Branch, where six feet of non-plastic clay, of fine quality throughout, is shown near the bed of the creek. The top of the limestone appears at a short distance from this exposure at the same level, showing that the fire-clay is separated from the sub-carboniferous rocks by only a few feet of rock. Section 28, plate 8, gives the general arrangement of the rocks in the lower part of the hills. Nearly the same order is shown at Mr. Kibby's and at Elwood's opening of Coal No. 2 on Barrett's Creek. These, with the "Potato Hill" section on Tygert's Creek, already given, and following section from the observations of Mr. Moore, furnish a key to the economic geology of this region:

STEWART SECTION.

Clay shales.	
Stewart ore (main block).	
Slope	65 feet.
Block ore.	
Slope	165 "
Thin coal.	
Slope (shales)	45 "
Conglomerate sandstone	30 "
Non-plastic fire-clay	6 "
Covered (shales)	15 "
Limestone.	

Coal No. 3 would doubtless be found a short distance below the main block ore, or about 240 feet above the conglomerate sandstone, over all this region. The thickness and value of the bed of coal can be determined only by trial. It is probable that it will be found in workable thickness, as at other points along this belt of country.

The valley of Barrett's Creek presents geological features which are easily comparable to those of Everman's Creek, yet changes are introduced which give to it a geology in some respects peculiar to itself. The absence or slight development of conglomerate sandstone is notable in the topography of this region, and this becomes an interesting feature when it is remembered that only a little way to the south the conglomerate becomes much more prominent than on Everman's Creek, rising in cliffs from 80 feet to 100 feet high. The question arises whether the absence of the greater part of the conglomerate formation in this valley is real or apparent. At first thought it seems incredible that a formation 100 feet in thickness should almost entirely disappear within a distance of three miles, and that it should become prominent again a little further on; and this might easily lead to the supposition that the change is in the character of the rock rather than in the disappearance of the formation. This supposition seems most natural from the changes known to occur at many points higher up in the coal measures, in the rocks of a given geological level. But in the instance in question, and generally where the conglomerate sandstone is wanting, it is found that the thickness of the formation is reduced to the thickness of the underlying shales, as in the section on Coal Branch, in Greenup. In the absence of the non-plastic fire-clay bed, the sub-conglomerate shales are not, in such instances, readily distinguishable from the shales above. This bed is not exposed, that I can learn, in the valley of Barrett's Creek. The limestone of the sub-carboniferous period rises above drainage in several localities, however, and it is probable that the fire-clay is present in some parts of the valley, and that the lower member of the conglomerate formation has some thickness

over the greater part of this region, as it is usually present, unless cut out by the thickened conglomerate sandstone. It is evident, however, that the rocks which properly follow the conglomerate formation in the order of superposition, begin at no considerable distance from the limestone, as shown by the position of Coal No. 1 and the overlying beds.

Mr. Andrews reports in Ohio a number of isolated patches of conglomerate of considerable thickness, which thin out in all directions, until no trace is left of the formation, showing an inequality much greater than is found in this field. With respect to the overlying rocks, however, the instances mentioned in Ohio do not furnish an exact parallel; for, in this section, the order of the beds above is generally preserved, notwithstanding the inequalities of the top of the conglomerate sandstone. Coal No. 1, so far as known, is in no instance interrupted by the thickening of the conglomerate; nor does the thickness of the shales below Coal No. 1 appear to be increased by the disappearance of the conglomerate, beyond what follows from the union with the shales below. The general section of this region does not, therefore, necessarily differ materially from that of Everman's Creek, or from that of the Sinking Creeks, as regards the rocks above the conglomerate. Section 23, plate 7 (above Bull's Eye Spring), shows three coals and the main block ore. A comparison of this section with the sections on Everman's Creek shows little variation in the whole thickness of the rocks included to the main block ore.

Coal No. 3 is here a cannel coal, or part cannel; but this fact does not present any serious objections to the reference of this bed to Coal No. 3, which is usually a bituminous coal. Instances of a change of the whole or a part of a bed from the one to the other are not uncommon, as will be seen from a statement further on of the number of coals known to be, wholly or in part, cannel at some point or points. A section at Bull's Eye Spring shows a block ore 20 feet to 25 feet above the limestone, followed by shales mostly, to a block ore 40 feet higher up. A coal stain is shown still above. At Mr. Lewis's

and on Stand Branch, Coal No. 2 is about 90 feet above the drainage, and about three feet thick. The identification of these coals is not so perfect as might be wished. I have referred them to Coal No. 2 as the most probable solution of the question of equivalency from what is known of the geology of this region. But it must be acknowledged that the evidences on which this reference is based are not entirely satisfactory, from the exceptional characters which appear in these valleys. It is evident that the dip of the rocks to the eastward is considerably greater than the fall of the creek from Bull's Eye Spring to the Little Sandy.

Coal No. 1 occurs near the bed of the Little Sandy, opposite Grayson, apparently not in such thickness as to be workable. Two coals follow in the order given by Mr. Lesley. (Volume IV, page 459.) The upper one, which is of workable thickness, may be the equivalent of Coal No. 3, though this would involve a considerable shortening of the section in this region, as compared with Everman's Creek section, and as compared with section 23, plate 7. At Grayson, and extending around into the valley of Bennett's Creek, a band of sandstone, five to six feet thick, is found, which makes a fine building stone. It is exposed around the foot of the hill, about 40 to 50 feet above the bed of Little Sandy, on the west side only, rising with the other rocks to the westward. It abounds in well-preserved impressions of stigmariæ. A coal stain shows directly above this rock. A similar bed has been noted at many points; west and north, frequently with a coal stain immediately above, as in the road just above Argilite Mill. It is not probable that this similarity may be accepted as sufficient evidence of equivalency, however, though such a bed, extending over a considerable field, would aid very much in making out the true stratification of the country. I have not found, in the country west of the Little Sandy, any bed of rock that is persistent both in character and place over an extended range of country; and, indeed, of some the beds of coal and of ore the same may be said with respect to place; for although, throughout the whole belt of country, there is such an arrangement of

beds as to make the general section an approximate guide for the whole area, yet it is by no means probable that all the beds are continuous at precisely the same geological level. This remark is especially applicable to Coals 2 and 2 A, which are less constant in position than the other beds.

Coal No. 1 is less variable and more easily identified, but it is not so regular in its place and in its relation to other beds as to be always identified with certainty. Coal No. 3, on the other hand, holds a place so uniform in the series, that it may be traced with ease over most of the region, and may be confidently relied on as a guide or base from which the beds above and below may be determined.

Southward from Barrett's Creek the conglomerate immediately attains a thickness which makes it a very important feature of the country. The great body of this formation begins in the Little Sandy valley, with the masses of coarse sand rock exposed in Little Sinking; the detached masses noticed on Everman's Creek, and other branches of the Little Sandy, being outlying masses only, along the northern border of the formation and along the eastern border of the narrow northward extension of the conglomerate in the Tygert's Creek valley. The cliffs of the Sinking Creeks and of Clifty Creek rise to such a height as to reduce somewhat the thickness of the coal-bearing rocks in the country drained by those creeks. Near the Little Sandy, where the greater part of the formation is below drainage, the hills include Coal No. 3 and the main block ore. The rest of the section is not shown as completely as on Barrett's Creek; but Coal No. 1 is present along the Little Sandy west of the river, and would doubtless be found generally through this region. The stain has been noticed in the divide between Tygert's Creek and Sinking Creek. At the head of Dry Branch of Little Sinking, on the place of Mr. James, the following section is shown:

Coal toward the top of the hill, thickness not shown.		
Sandstone and shales about	90	feet.
Coal	2½	"
Shales and sandstone	35	"
Coarse sandstone	25	"

Some ores were found still lower in shales. On the Pleasant Valley side a similar ore is found on Mr. Harris's place, near the house, 25 to 30 feet above the top of the conglomerate, which is little more than 30 feet thick at this point. One hundred and eighty feet up from this ore is a blue, somewhat silicious limestone, similar to a band noted on a high point at Thompson bank, Kenton Furnace. This rock has been noted at the head of Long Branch of Everman's Creek, at about the same geological level, and at a few other points. It is less prominent, however, than in Ohio, as described by Mr. Andrews. The second coal in the section at Mr. James's is reported as cannel, or part cannel. It was covered at the time so as not to show its thickness and character. In section 24, plate 7, a cannel coal is shown, opened near the top of the hill, which is probably the same bed, and the equivalent of the Barrett's Creek cannel coal, or No. 3 Coal. This reference is made from evidence that is not altogether satisfactory. Near the same point, however, a thin cannel coal was opened lower down, and a thin coal in bituminous slate is shown just above the top of the conglomerate. The hills in this region generally include these beds, and doubtless the ores at the base of the general sections, while the highest hills would probably include the main block ore. The section up to that ore is considerably shortened in this region. The conglomerate formation is in some of its layers a true conglomerate, otherwise it is a very coarse-grained, somewhat ferruginous sandstone throughout. Cross-stratification, as mentioned in other localities, is very strongly marked on the faces of the cliffs as exposed along the creeks from the west. The direction of the inclination of this cross-bedding is very uniformly to the southeast. To this I have observed no important exception in this region. Nearer the Big Sandy, in Lawrence county, there is less uniformity in this respect, though this is still the predominating direction.

East of the Little Sandy, in this region, the branches are comparatively short, resembling somewhat in this respect the Tygert's Creek valley; and the ridge which extends down to

the first considerable branch from the eastward includes about 100 feet more of the coal-measure rocks than those to the west, or to the "ferriferous limestone,"* which, like the sub-carboniferous limestone, has at the top a band of ore—"limestone ore," as known in this region. The ferriferous limestone varies in thickness, when present, from one to eight feet. It is entirely wanting over a large part of the field where its horizon is above drainage. The ore is not limited to the area of the limestone, however. It continues to mark the place of the limestone over a considerable additional area, where it is easily recognized from its constant character.

East of the Little Sandy river the conglomerate is not found above the drainage, except at points close to the river. Coal No. 1 is near the creek bed in the valleys of both Deer and Wolf Creeks. In the former the following section is shown near Mr. McDavid's:

Sandstone	15 feet.
Thin coal.	
Shale and sandstone	10 "
Cannel and bituminous coal	2 "
Sandstone and shale, about	90 "
Coal, with nodules of ore above in shales	3 "
Shales, including a calcareous band and thin coal	50 "
Bedded coarse sandstone (top of conglomerate).	

Section 33, plate 9, at Mr. Ball's, on Wolf Creek, shows Coal No. 3 and the main block ore, and a high point in the divide between these creeks and Little Fork includes the limestone ore, as in the following section:

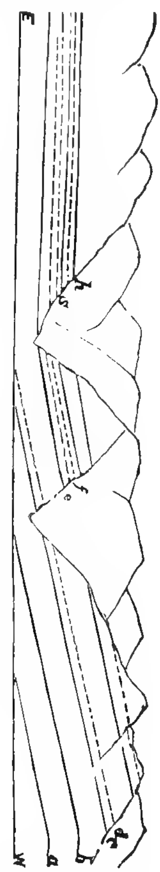
Covered slope	10 feet.
"Limestone ore."	
Shaly rock	15 "
Coarse sandstone (cliff)	20 "
Slope of hill	300 "

Coal No. 5 would probably be found immediately under the coarse sandstone which caps most of the points of this dividing ridge, as it is present in considerable thickness in the valley of Little Fork. The distance from Coal No. 3 to the limestone ore in this region is from 110 to 125 feet. The whole thick-

*This limestone, which marks a distant horizon, both in Eastern Kentucky and in Ohio, along the opposite side of the river, has come to be known as the ferriferous limestone from the nomenclature of Mr. Andrews; and as this term is unobjectionable, and in some sense descriptive, it will be used in this report.

ness from Coal No. 1 to the limestone ore is about 320 feet. Coal No. 4 is wanting in this region, or so covered as to give no indication of its presence. The lower block ore has not been opened, though it would probably be found at its proper geological level. The beds which recur in the western slope of the ridge are, therefore, Coal No. 1, the lower block ore? Coal No. 2, here part cannel, Coal No. 3, the main block ore, and Coal No. 5—some of the highest points including the "limestone ore." To the northward this ridge runs across the general line of outcrop to the westward, and therefore includes less of the rocks above Coal No. 3. North of the mouth of Little Fork, however, the western slope of the Little Sandy valley includes more of the beds above; the river, by an eastward bend, recrossing the line of outcrop.

The Little Fork of Little Sandy, and its tributaries, drain a large tract of country which lies between the ridge just considered and the range of hills that form the divide between Little Fork and the waters of Blaine, and of East Fork of Little Sandy. From the top of the ridge on the west, to the center of the basin formed by the two ridges, the dip of the rocks is more marked than elsewhere on the Little Sandy, and this is especially true at Willard, where such a depression of the rocks of the whole series occurs as to form a well-defined geological basin.



a. Coal No. 1. *b.* Coal No. 2. *c.* Coal No. 3. *d.* Block ore.
e. Coal No. 5. *f.* Limestone and kidney ores. *g.* Coal No. 7. *h.* Coal No. 8.

The annexed diagram represents approximately the depression of the coal-measure rocks along a line eastward from Graham Hill, through the hills between Lost Fork and Bell's Trace. A section along a north and south line, intersecting this on Dry Fork, would also show a depression, the lowest point of which would be near the inter-

section of the two lines, the greatest dip being northward to that point. The coals and ores on Little Fork, and in the Willard and Dry Fork region, have been so generally developed as to afford a key to the mineral resources of the surrounding country. The beds that are known to be present in some parts of this region are shown in sections on plate 26, and sections 38, 39, and 40, plate 11. The formations exposed on the branches of Little Fork from the westward are included between the "limestone ore" and Coal No. 1, though the varying dip and the windings of the valley give considerable variation to the sections on the different branches. John's Run and Muddy Branch show the whole series, while Hilton's Branch cuts through only the upper part of this series. Field Branch and Huff's Run probably show only the middle part of the series, including Coal No. 5, Coal No. 2, and the intermediate beds. The hills between Little Fork and Dry Fork, in Carter county, include the beds between Coals 5 and 8, with overlying rocks, which belong to the Mahoning sandstone period. Southward, in Lawrence county, the dip changes to the north, as previously described, so that the hills include the lower beds up to and above the "limestone ore." A line drawn from the mouth of Cane Fork of Dry Fork to a point a little south of Louisa will mark very nearly the origin of the rapid rise of the rocks to the southward. At the head of Dry Fork the rocks below Coal No. 3 appear to be somewhat reduced in thickness. A section at Mr. Hensley's is as follows:

Top of point.	
Covered slope	106 feet.
Impure limestone (yellow lime)	3 "
Shaly rock	25 "
Small kidneys of ore in greenish shale.	
Covered (shales and sandstone)	50 "
"Limestone ore"—abundant.	
Mostly sandstone	100 "
Shales (place of Coal No. 3).	
Sandstone (mostly with shale at base)	180 "
Coal No. 1 near bed of creek.	
Shales.	

The thickness of rocks between Coal No. 1 and the "limestone ore" is 280 feet. At Graham Hill the thickness is 317 feet. On Big Blaine it is about 250 feet, as will be seen from

sections in that valley. Coal No. 3 is shown at the head of Dry Fork, under 15 feet of sandstone, exposed in a cliff or overhanging rock. (Section 6, plate 26.) Coal No. 5 is not seen here, but is shown at the head of Equal Fork on the east side of the divide. (Section 66, plate 18, and near Willard, section 4, plate 26.) It would probably be found generally at a level, varying somewhat from its normal distance of 35 feet below the "limestone ore." Coal No. 7 appears to lose its importance in this direction, though no effort has been made to open the bed in this region. Its presence is shown in section 66, plate 18, along the ridge between Dry Fork and Big Blaine, and it would probably be found in some thickness in all the hills which include the rocks of this geological level.

Cane Fork flows along near the foot of the steep northward dip, having its bed at a lower geological horizon than the branches to the northward, however, from a gentle rise of the rocks to the point from the center of the basin. Little mining has been done on this stream. A section at the mouth (section 2, plate 26) shows the "limestone ore," with a greatly shortened section above, in which the Coals 7 and 8 are apparently wanting or thin. Above the falls Coals 6 and 7 are shown, while a thickening of the sandstone below Coal No. 6 cuts out the "limestone ore." (Section 48, plate 13.) Higher up a coal stain is shown under the second impure fossil limestone,* the place of Coal No. 10, which is a cannel coal further east.

Bell's Trace and Lost Fork are so similar, geologically, that little can be said for the one that is not applicable to the other. Coal No. 7 is above the bed of both valleys for a distance of two or three miles; Coal 8 for four to five miles; and the first impure fossil limestone is shown in the beds of both streams near the head of the valleys, at the foot of the main ridge. Very perfect specimens of characteristic fossils are easily ob-

*Above Coal No. 8, 10 to 25 feet, and 100 to 125 feet higher, with others in the series still above, impure fossil limestones occur over a wide range of territory, varying in thickness, but never more than six or seven feet. I have for convenience called these the 1st, 2d, 3d, and 4th impure limestones. (See section 71, plate 19.) In character the 1st and 2d impure limestone bands vary from a somewhat impure limestone to a fine-grained silicious rock, resembling limestone, and filled with fossils characteristic of the carboniferous period.

tained in both places. On Lost Fork the kidney ores, associated with Coals 7 and 8, are mined, as also at one point the so-called Rough-and-Ready ore, just above the second impure limestone (section 46, plate 13). At the top of a high point on the head of Lost Fork, a third conglomerate sandstone occurs, as shown in section 1, plate 28, nearly 200 feet above the second impure fossil limestone. The pebbles found in the soil at the top of the hills around Willard are derived from this rock. No conglomerate rock has been observed at this geological level at other points in Carter or Boyd counties.

A greater thickness of rock is exposed from the base of the hills west of Willard to the tops of the hills, at the head of Lost Fork and Bell's Trace, than in any other valley in this part of Eastern Kentucky. The combined section shows the entire series, from Coal No. 1 to the highest coal-measure rocks of this field, or a thickness of about 750 feet. An opportunity is offered here, therefore, to verify the stratigraphical determinations for the rest of the field, as shown by profile sections I, II, and III. It will be noticed that this section at Willard so fully corroborates the arrangement of beds, as shown in both the profile sections and the general section, that there is left no room for doubt as to the correctness of the classification as here adopted.

An impression prevails to some extent that Coal 8, as shown in sections 3 and 7, plate 26, is the equivalent of the Coalton coal, rather than the coal next below. A careful comparison of these sections with sections in Boyd county will show the incorrectness of this view. The occurrence of the yellowish, impure limestone, which marks the place of, and which sometimes accompanies the "bastard limestone ore," of Boyd county, and the coarse sandstone (cliffs) above, as shown at many points in both Carter and Boyd, are of themselves conclusive on this point; but the relation to beds below—the kidney ores and the limestone ore—beds which preserve a remarkable uniformity, both in character and in place, puts the question of equivalency beyond a doubt. The bed of coal at the head of Lost Creek, at Mr. Roberts', as well as the Gar-

ner Creek coal, is, therefore, the equivalent of the Hatcher coal.

The geological features of Davy Run are similar to those of Lost Creek. The coals exposed are No. 6, which is thin, as at Willard, and Nos. 7 and 8, associated with the kidney ores. The limestone ore is not present in its usual thickness, except, perhaps, towards the mouth. The opening of Mr. Ellwood, on Deal Branch, is probably in Coal 8, and not Coal 7, as was supposed. Coal 3 and the main block ore would probably be found at the mouth of the run, considerably above drainage.

The valley of Straight Creek presents, near Mt. Savage Furnace, the rocks of the series from below Coal 3 to the Mahoning sandstone, with a considerable dip to the southeast. Section 37, plate 11, shows the height above drainage of such beds as are exposed at this point. At the head of the valley, the first impure limestone band is exposed in the bed of a branch, and along the sides of the valley, at a level 50 to 100 feet lower than its place at the furnace. The valuable coals and ores of Mt. Savage Furnace are below this band, and below drainage at the head of the main creek; the dip of the rocks and the fall of the stream tending to place the rocks, which are high up in the hills, at the furnace, below the beds of the branches at the head of the valley. On Lefthand Branch, however, the upper beds are above drainage to the head of the valley. As reported by Mr. Moore, a general section for Mt. Savage would include Coals 3, 4, 5, 6, 7, and 8, with the ores usually associated with these beds. Coal 4 and the main block ore have been noted only on the Stinson Creek side, but would probably be found in the valley of Straight Creek. Coals 5 and 6 have not been worked. Coal 7 is mined at a number of points for local use.

Sections at different points in this region show some considerable departures from the order of the general section, some beds being cut out locally by heavy masses of sand-rock, others occurring at such intervals as to make the classification uncertain in some minor particulars.

Stinson Creek shows, in most particulars, a repetition of the geology of Straight Creek. Much less has been done to develop the resources of this valley. Section 31, plate 9, shows Coal 3 with the main block ore, and near the top of the section Coal 7, associated with the kidney ores; Coal 4, the Stinson Creek cannel, is also present, and no doubt the other beds would be found. The dip of the rocks in this region, as determined by levels run by Mr. Goodwin, is the reverse of that of Straight Creek, or slightly to the northwest. Near the mouth of Stinson, coals were reported by Mr. Jos. Lesley, which no doubt represent Coals 1 and 2.

Wilson's Creek shows some important changes in the rocks exposed on Stinson and Straight Creeks. A heavy mass of sandstone near the head of the creek interrupts some of the regular beds, and makes the equivalency of other beds, especially those below, uncertain. A section near Mt. Savage cribs shows the yellow kidney ore near the top of a low hill. The following is the section at this point:

Slope to top of hill.	
Yellow kidney ore.	
Shales and sandstone	25 to 30 feet.
Sandstone (cliff)	40 "
Covered space	5 to 10 "
Sandstone (cliff)	40 "
Coal, thickness not shown.	
Sandstone and shale	25 to 30 "
Blue block ore—"Wilson blue block"—in bed of creek.	

On the Star Furnace road the following section is shown:

Top of hill.	
Shales, with kidney ore	50 feet.
Covered space, S. S. at base	50 "
Slate ore, with fire-clay.	
Sandstone mostly	55 "
Coal, thickness not shown.	
Sandstone and shales	25 "
Blue block ore in dark shales.	

It is probable that the so-called slate ore is the representative of the limestone ore in this valley, as found at other points; while the blue block ore is more likely to be a local bed, though not far removed from the place of the main block. Towards the mouth of the creek the section is less disguised, and would show the rocks from Coal 2 to the limestone or slate ore. Little has been done to develop the coals in this valley.

Kane Creek, like the preceding, rises in the ridge between the waters of main Little Sandy and of East Fork. This ridge extends along a line nearly north and south from the Lawrence county line to East Fork; and as the average dip is south of east, the rocks which are below the drainage at the head of Straight Creek and of Lost Creek rise towards the tops of the hills along the northern extension of this ridge. This rise is abrupt from the head of Straight Creek to the head of Stinson. At the former place, Coal 7 is below drainage; at the latter, it is well up in the ridge, as seen in section 31. The reverse dip mentioned on Stinson is opposed to this rapid rise, forming an anticlinal, which cuts across the ridge by the direction of its axis, but which does not appear to be continued out into the main valleys on either side. Further north, the general inclination of the surface of the country towards the Ohio will largely account for the gradual disappearance of the upper beds of this region, at the tops of the hills. At the head of Kane Creek Coal 8 is opened near the top of the hill. Section 36, plate 10, shows the beds which are opened in this region. The covered space includes the horizon of several important beds, as will be seen from the general section. Whether they are present in workable thickness is uncertain. The slate ore (L. ore) is shown at a number of places near the head of the valley, while Coal 4, the Hunnewell cannel, becomes prominent to the northward. Section 30, plate 9, near Hunnewell Furnace, shows the economic geology of this region more completely. A fine building stone is exposed 15 feet below Coal 3, which, at this point, is charged with petroleum, and is easily worked before it is hardened by exposure. Nearly the same section is shown at the head of Turkey Lick Creek. The hills at the head of Cannel Branch include Coals 7 and 8, with the accompanying kidney ores, as at the head of Kane Creek. (Section 36.) The dip to the eastward is slight in this valley, and the hills west of Hunnewell include the series from Coal 2 to Coal 6. Near the Little Sandy Coal 1 and the lower block ore would probably be found above drainage. Coal 2 does not appear to be prominent in this region. A

thin coal shown in the railroad cut above the machine shops of the Eastern Kentucky Railroad Company is in the place of Coal 2.

The valley of Culp's Creek differs from that of Kane Creek in few particulars. The cannel coal is apparently wanting, though it is found on East Fork, near the mouth of Indian Run. A thin cannel slate marks the place of the cannel coal at one place on the head of Culp's Creek. Section 35, plate 10, shows most of the geological features of this valley. A thin coal is shown immediately under the ferriferous limestone. Section 3, plate 27, near Mrs. Callahan's, and the Pea Ridge section, near Hunnewell, show the same bed. At no place in this region is this coal known to reach a workable thickness. But while it is not of sufficient thickness to be counted as one of the coals of this field, it presents an interesting feature as being the representative on this side of the Ohio of the Nelsonville coal, which Mr. Andrews, of the Ohio Geological Survey, describes as immediately below the ferriferous limestone. It appears from this, that while there is a marked similarity between the arrangement of the beds of Southwestern Ohio and of Eastern Kentucky, the most important beds of coal are not continuous across both fields, as supposed by Mr. Andrews.*

East Fork, along its westward course in Greenup county, presents, in the hills on either side, geological features of which sections 1 and 3, plate 27, give the outline. The heavy sandstone above the ferriferous limestone and ore replaces the shales and coal usually found from 15 to 20 feet above, and in some places the yellow kidney ore, which otherwise catches in the tops of the hills east of the mouth of Ash Creek. Near the mouth of Indian Creek the cannel coal (No. 4) is opened about 40 feet above the bed of the creek, and the limestone ore is found under the sandstone cliffs nearly 100 feet above,

*The identification of the Coalton coal (No. 7) as the equivalent of the coal below the ferriferous limestone in Ohio by Mr. Andrews, report of 1870, page 211, was incorrect, as will be seen from the numerous sections which include the rocks of this geological level. The ferriferous limestone, when present, is quite uniformly 60 feet below the Coalton coal. Mr. Andrews was misled by assuming that the coal 20 feet below railroad grade, at Summit Station, is the same as the Coalton, or the same as the Eastham coal, it being in fact a much lower bed, or Coal 5 of this report, about 35 feet below the ferriferous limestone.

with "rolls" of the ferriferous limestone. The section on Ash Creek, near old Steam Furnace, shows the kidney ores and Coal 7 above in the top of the hill. (Section 34, plate 10.) Nearly the same rocks are shown at old Caroline Furnace, and on Chinn's Branch (section 33, plate 10), though the hills are not high enough to include Coal 7. The cannel coal has not been found on Ash Creek or on Pond Run, but it is present in good workable thickness on Chinn's Branch, at the level indicated by section 33.* In the valley of Yewland's Creek the hills include no important beds above Coal No. 3 and the main block ore, and near the Ohio a heavy sand-rock replaces the latter. (Section 6, plate 27.) Coal No. 3 is opened in the hill between Deer Hill Branch and Hood Run, on the road to Riverton and Greenup.

From the ridge, between the waters of the main Little Sandy and of East Fork, the dip to the eastward is more marked to the center of Williams' Creek valley than in the belt of country to the west. Eastward, from the northern extension of the line of this ridge to the Ohio, the dip of the rocks is apparently a continuation of that from the west, as in profile section No. 1. A geological ridge extends eastward along the head waters of Hood Creek to Summit Station, on the eastern division of the Lexington and Big Sandy Railroad, and to the head waters of Keys' Creek, changing the inclination of the rocks exposed on either side northward toward the Ohio river, and southward for a short distance to the valley of East Fork and of Shope's Creek. From a point about two miles east of old Caroline Furnace to the eastern border of the "Flat Woods"† country, very little change of level takes

*The mines of the Maysville Company were abandoned at the time this region was visited, but work has since been resumed, and the increased thickness of the bed, as recently discovered, promises a large supply of this well-known coal.

†A section of country around Bellefont Furnace, and back of Ashland, which is characterized by low, flat hills, is known as the Flat Woods. The tops of these low hills, which are less than half the height of the surrounding hills, appear at a distance to form the bed of a basin. A great number of water-worn pebbles and boulders are found scattered over the whole region. These pebbles are evidently derived from the rocks of this region, being of quartzose rock or of sandstone slightly modified by the action of water. There is apparently no evidence of glacial action in the shaping and distribution of these pebbles and boulders. They are not limited strictly to the Flat Woods hills, but are also found at about the same height several miles above the mouth of the Big Sandy, thus connecting both the Ohio and the Big Sandy with this phenomenon. A collection of the pebbles has been made for the State collection.

place in the beds as exposed along the river. Sections 49 and 50, plate 13, show the essential features of the geology of this belt of country. The low hills of the Flat Woods include the ferriferous limestone and Coal No. 6 only at the top, as shown in the profile section. The higher hills around the Flat Woods include the beds up to the Mahoning sandstone, as in section 1, plate 25. An isolated hill in the bend of the river includes the rocks equivalent to those of this section; but all efforts to find the coals which give to this horizon its special interest seem to have failed. It is not unlikely that the thickening of the sand rock above Coal No. 6 has changed the section, so that Coal No. 7 may not be present in its full thickness; and it is possible, also, that Coal No. 6 may have lost its importance at this point; but the supposition is a contradiction of all the probabilities of the case, as drawn from the sections shown on all sides. This hill is at a point where the northward inclination of the formation is modified by the rapid eastward dip of the Big Sandy valley, and, therefore, the height above the river of these beds is not indicated by the opening of Coal No. 6 around Ashland, but rather by the openings at Sheridan. Hood Creek and its tributaries flow down from the geological ridge described above; and, therefore, though the hills along the head of the creek are much higher than those along the river, the rocks exposed near the top of the hill are of the same geological level as those shown in section 1, plate 25, and section 54, plate 15: the shale series containing the kidney ores and Coal 7 (and Coal 8, where that is present) being near the top of the hill.

The western slope of the Williams' Creek valley presents a similar geological field. The shale series, with Coals 7 and 8, and the associated kidney ores, is near the top of the ridge, capped by a massive sandstone at the highest points. Along Williams' Creek, as at Coalton and Rush Station, this series begins 30 to 40 feet above the bed of the creek; Coal 7, the main Coalton seam, being about 90 feet above the creek bottom. Section 42, plate 12, shows the geology of Brush Creek, the fall of the stream being about the same as the dip; so that,

with some allowance for local variations, the section stands for the whole valley. On Straight Creek and Furnace Branch, the beds shown in section 51, plate 14, and section 7, plate 29, are found. Coal 3 is exposed on Williams' Creek below the mouth of Straight Creek. The coals of this region have been mined for local use only, the great body still remaining untouched. A high point between Straight Creek and Mile Branch, and a little more than a mile west of Coalton, shows the second impure fossil limestone, which is so well-marked a feature further south. There it is about 165 feet above the Coalton coal.

Mile Branch and Rachel Branch, and Williams' Creek, above Rush Station, present the same series of rocks, with some changes in character and thickness, as in section 52, plate 9, and section 8, plate 29. The rocks of the same geological level are relatively lower, however, and the hills are capped by a greater thickness of the overlying coarse sandstone. In Boyd county the rocks above the kidney ores are exceedingly variable in character. At some points a massive sandstone (the Mahoning sandstone of Owen) follows the so-called bastard limestone, or the ore which represents it, forming overhanging cliffs, which resemble somewhat the conglomerate sandstone cliffs of Tygert's Creek. At other points a shaly sandstone, or even a shale, continues the series upward from the same point for more than 100 feet. The term "Mahoning" sandstone has, therefore, come to have a very indefinite meaning, as applied to the rocks of this section. I have used the term, without accurate limitation, as applying to the rocks which follow the shale series containing Coals 7 and 8, and which often appear in characteristic ledges and cliffs immediately above this series. In Carter and Boyd these ledges or cliffs vary from 30 to nearly 100 feet; in the latter case, more or less interrupted by shales, with one or more thin beds of coal. Whatever may be the equivalency of these rocks, they form the base of a series which stands in marked contrast with the rocks below, as regards both the number and the value of the beds of coal and of ore included. The continued dip to the

eastward, therefore, reduces the thickness above drainage of the most productive measures. Eastward from Williams' Creek the dip is slight. At East Coalton, and at Old Trace, it is only 20 feet lower than at Coalton. At Mr. Kouns', near the mouth of Old Trace, Coal No. 7 is about 40 feet above the bed of East Fork, the fall being less than that of the stream. It occurs in the bed of Ellington's Bear Creek, about a mile from the mouth. These points are along a line nearly east to west, and do not represent the full dip, which is toward the southeast in this region. At Mr. Wm. Davis', Coal No. 7 is below the bed of East Fork, and the rocks which form the steep faces of these hills are those of the so-called Mahoning sandstone, between two heavy layers of which Coal 9 occurs, as at the head of Lost Creek. Compare section 3, plate 28, with section 7, plate 26.

At Mr. McBrayer's bank, on Four Mile Creek, a section of the hill (section 2, plate 30) shows Coal No. 7 10 to 15 feet above the bed of the creek, with Coal 8 shown as a stain only, followed by the "Bastard limestone," here a yellowish, impure limestone, as in Lawrence county. The ore above is a local ore, and of little value. On the place of Mr. Kouns, on East Fork, a local ore is opened, which is several feet in thickness. It is a slaty ore, said to have been used at the Buena Vista Furnace. The following section shows the place of this bed:

Covered slope.		
Slaty ore (local bed)	2½	feet.
Sandstone and shale	20	"
Heavy sandstone	25	
Coal (No. 7)	3½	"
Shales with bands of sandstone	25	"
Kidney ore.		
Shales and sandstone	20 to 25	"
Coal (No. 6), thickness not shown.		
Fire-clay.		

In this region, Coal 7 is immediately under a thick-bedded sandstone as in this section, and the so-called red kidney ore above is generally wanting, though at some points, as near the school-house above Mr. Kouns', a few large "blue" kidneys are imbedded with the thin layers at the top of the ledge.

Garner Creek flows for the greater part of its length in rocks of the same geological level. Section 60, plate 16, on

Pigeon Roost Branch, shows Coal 8 with its usual surroundings. The opening here shows 4 feet of good coal, 10 to 15 feet above the branch. The Coalton seam is below the drainage. Section 9, plate 28, near Mr. Pritchard's, also shows Coal 8, with a coarse sandstone cliff above, resting on the usual band of impure limestone.

Bolt's Fork presents the rocks still higher in the series, Coal 8 having fallen below drainage. At Sandy Furnace, the first impure fossil limestone band is exposed in the bed of the creek. Section 7, plate 28, includes also the second fossil limestone, with the Rough-and-Ready ore above and a thin coal below, the representative of Coal 10. Coal 9 would probably be found thick enough for local use. Towards the mouth of Bolt's Fork the rocks fall below the drainage, so that at the mouth the second fossil limestone is only 55 feet above East Fork. No trace of coal is seen with this band at this point.

East Fork above runs nearly parallel with Bolt's Fork, and the same series of rocks is exposed along the valley, except that, near the head, Coal 8 rises above the bed of the fork. (Section 65, plate 18, at Mr. Webb's). Of the branches of East Fork from the east, only Shope's Creek and Marsh's Run present a considerable thickness of the more productive coal-measure rocks. (Sections 4, 5, and 7, plate 25, and section 62, plate 17.) These streams flow in the geological basin formed by the depression of the rocks south of the geological ridge already described. Sections 55 and 56, plate 15, at Summit Station, and on Shope's Creek, show a rapid dip to the south—70 feet—in a little less than two miles. From Tunnel Station, on the other hand, to the valley of East Fork and Shope's Creek, a dip to the northward of 50 feet is found in about the same distance. To the eastward, along both Shope's Creek and Marsh's Run, the rise of the beds of the creeks gradually leaves the rocks of the series below the Mahoning sandstone, below the drainage, though a slight rise of these rocks is shown along Shope's Creek towards the ridge which forms the western boundary of the Big Sandy valley. Toward the head of all the branches of East Fork which rise in this

ridge, the same western inclination is observed. Laurel Creek flows in the upper part of the series below the Mahoning sandstone, cutting through the horizons of Coals Nos. 7 and 8. Little is known of the coals in this valley, except the fact of their presence. On Ellington Bear Creek, except the coal shown in the bed of the creek near the school-house, no beds are exposed above drainage. Coal 8 appears to be wanting in this valley, though very likely it might be found above the sandstone which extends along the creek in a ledge, which resembles very much the heavy sandstone over Coal 7, in the East Fork region.

The streams which flow into the Big Sandy from the ridge on the west cut through rocks which present, in the different sections, geological features quite contradictory in details, but which, nevertheless, belong to one and the same series of rocks. The dip from this ridge to the center of the valley, like that along most of the eastward-flowing streams, is uninterrupted, though such variations in the steepness occur as to give to the rocks of the same geological level, as exposed along the Big Sandy, undulations which are well-defined from the river level.

Keys' and Catlett's Creeks belong to this slope, though they empty into the Ohio. The sections on these creeks show more of the productive coal-measure rocks than are exposed further south in Boyd county. These rocks have already been described somewhat in detail. Sections 77, plate 21, and 81, plate 22, show both these and the overlying rocks which make up the great body of the hills. The ferriferous limestone is not present in these valleys, and the "limestone ore" is found at one point only—at a cut on the coal railway on Keys' Creek–where it is shown closely adhering to the coarse overlying sandstone. A local recent ore deposit, two and a half feet thick, is found at one point on this creek with well-preserved impressions of leaves and stems of the species of trees now growing on the hills above. It is known as the "Honeycomb ore;" and if found in sufficient quantity, it would no doubt prove a valuable deposit.

Coal 7 is also opened near the bed of the creek. A similar section, beginning near the bed of the creek with Coal 8, is shown on White's Creek (section 2, plate 25, and section 82, plate 22), and with such undulations as are marked by the rise and fall of the cliffs along the river, the rocks shown in these sections continue to form the western slope of the Big Sandy to the mouth of the Big Blaine. Sections 83 and 84, plate 22, at the mouth of Bear Creek and of Blaine, and section 79, plate 21, at the head of Bear Creek, show some considerable changes in the character of the rocks; but at the same time they indicate unmistakably the continuation of the series as already described.

The geology of Lawrence county is a continuation of what has been seen in the adjoining counties of Carter and Boyd, with some important changes in the details of the formations exposed. From the northern boundary of Lawrence to a line drawn from Louisa to the head of Jourdan's Fork, the rocks exposed are the same as have been described on East Fork and in the Sandy valley. A slight rise to the southward begins near the county line—a rise that is modified by considerable undulations, especially near the Big Sandy, where Coal 8 is easily traced by openings on both sides of the river, at varying heights above high waters. The shale series which carries Coals 7 and 8, is not so clearly marked in this region as in Boyd; and apparently the former coal loses its importance, appearing only as a thin coal, or entirely wanting in some places. The kidney ores are also less regularly present, though shown at a few points near high water, or near the bed of the creeks. The so-called "red kidney ore" is more commonly represented in Lawrence county, as in the Big Sandy valley in Boyd. This will be seen from an examination of the sections given. Sections 71, plate 19, and 4, plate 28, on Jourdan's Fork of Lost Fork, show most of the characteristic beds in this region. On Long Branch, two miles from the mouth, the first impure fossil limestone is exposed in the bed of the creek. The same bed is exposed on Seed Tick Branch of East Fork, at about the same level. Near the mouth of Long

Branch a coal is opened in the bed of the creek near Mr. Belcher's, from which point a rapid rise to the Falls of Blaine takes place; and apparently, 30 feet higher up, is found at several points another bed under a heavy sandstone, reaching a height of 120 feet above Blaine at the falls, a mile distant, as shown in section 80, plate 21. Neither of these coals exceed 2½ feet in thickness, as exposed; and though openings made for local supplies of fuel seldom show the full thickness of beds, it is not likely, as appears from the best information available, that these beds will prove so valuable as to warrant extensive mining at present. The most important beds of Lawrence county, unlike those of Greenup and Boyd, are lower down in the series, and these are available in this region only by shafts of considerable depth. The continuation of the rise of the whole series to the southward effects, in a short distance, however, what a shaft must do for this region, as will be seen from a brief study of the geology of the country southward on the waters of Big Blaine, and on the smaller branches of the Big Sandy.

In the valley of Thompson's Fork, near the mouth of Peach Orchard Branch, 42 inches of good coal is exposed (section 4, plate 30), at a level which appears to be that of Coal 6. The variation from the typical sections of this country which is exhibited in section 4, and the wide intervals at which the coals are exposed, leave the equivalency of this bed somewhat in doubt. Reasoning from the indications which are gathered from the face of the hill back of Mr. Van Horn's at this point, the reference of this bed to Coal 6 seems most consistent with the facts. The shales above, with the kidney ore, closely resemble the greenish shales which contain Coals 7 and 8, but which are largely replaced by a coarse, friable sandstone. The presence of an ore deposit at the base of the coarse sandstone is a local feature which may prove to be a valuable addition to the mineral wealth of this locality. As exposed, it appears to be a well-defined layer of limonite ore, similar to the block ores lower down in the series, though it is more likely that it is a thickened band of the so-called kidney ore. The section

at the Falls of Blaine appears also to begin with Coal 6. On a comparison with the Thompson Fork section, this would seem to be no more than a repetition of that section with thickened parts, the bed of ore and of fire-clay in the latter occupying the place of Coal 8 in the former. This is shown not to be the case, however, by the occurrence of the first impure limestone (yellow limestone in Lawrence county) at the base of the thick sandstone of section 7, as shown along the continuation of the ledge on Long Branch; while on Thompson's Fork the same band is found at the top of the friable sandstone there exposed. Near Mr. McGuire's, three miles below Louisa, the rocks exposed in the river hills recall more nearly the order of the general section. (Section 2, plate 28.) The coals here have been opened only imperfectly, so that little could be seen as to the thickness of the several beds. On Cooksie Fork, at several points, Coal 5 is shown near the bed of the creek, under 25 feet of sandstone. (Plate 31.) Section 72, plate 19, on Crane Branch, just below the Brown place, where coal is exposed as just mentioned, gives a coal stain evidently of the same coal, and an ore that represents the limestone ore. From this point southward along the waters of Big Blaine, the "limestone ore" becomes a regular bed, which, with the ferriferous limestone often present with it, serves, as in Greenup, Carter, and Boyd, to make the identification of beds above and below comparatively easy. On the Twin branches slight traces of the limestone ore are found at the top of the thick sandstone ledge, which, near the head, forms a bench around the hill. Near Jourdan's Mill the same is shown above a coarse sandstone, which reaches in an almost unbroken ledge to the bed of Blaine, 120 feet below. Coal 3, which is very uniformly about 100 feet below the limestone ore, seems to be entirely replaced at this point. On the larger of the Twin branches near the school-house a thin coal is exposed, which is probably No. 3. The same bed is shown at the ford near Mr. Frank Carter's, under a coarse sandstone. At the top of the point on the opposite side, and along the ridge, 100 to 110 feet above this coal, and at the top of a high ledge

of whitish coarse sandstone, fragments of the limestone ore are found. At Mr. Burchett's, on Muddy Branch, below Jourdan's Mill, a coal is shown higher up; probably Coal 8. The following is the order of the rocks at that point:

Covered slope.	
Shale	10 feet.
Coal	2 "
Shales, with kidney ore very abundant	8 to 10 "
Coarse sandstone	25 "
Shales with coal stain	10 "
Sandstone	15 "
Covered to bed of branch	45 "

On the opposite hill, 25 feet above the kidney ore, or only a few feet above the place of the coal, the yellow limestone (the first impure limestone) is present in considerable thickness.

On Green Brier Creek, near Mr. Hutchinson's, the "limestone ore" is shown in shales by the roadside, 20 feet above the bed of the creek, and 90 to 100 feet above Blaine. This is the furthest east that I have observed this ore. On Two Mile Creek the stain of Coal 6 is shown near the bed of the creek for nearly the whole length of the stream. Near the schoolhouse, and at Mr. Wellman's, it is partially opened at the roadside. At Louisa the same bed is scarcely above the river bottom. The place of the limestone ore is, therefore, below the drainage in this region, if present. The probability is, however, that it is not present in the immediate valley of the Big Sandy, in Lawrence county, as no trace of it has been discovered, either along the river, where it would be exposed, or southward along Lick Creek, where the rocks of the sandstone series below the limestone ore rapidly rise to form the body of the hills. Some notion of the steepness of the dip, from the head of Lick Creek towards Louisa, may be formed from the fact, that, notwithstanding the fall of the stream, it flows, within a distance of six miles, across rocks which have a thickness of more than 250 feet. The fall of the creek is about 100 feet for this distance. The McHenry coal (No. 3) will therefore be found falling rapidly to the base of the hills northward, disappearing below the bed of the creek, about half way to Louisa. The top of the thick sandstone which rises above Coal 3 nearly 100 feet, is seen in the bed of Lick Creek near

the mouth, and it forms the cascade at the bridge across Two Mile Creek below Louisa, and also the Falls of Blaine. From the mouth of Lick Creek, therefore, the formations extend northward, with nearly a horizontal stratification. South of McHenry's bank the dip is not more than 10 feet to the mile. (See sections 86 and 87, plate 24.) The rise of the formations to the southward, in that belt of country which lies west-northwest, to the head of Cane Creek, is nearly as abrupt. On Daniels' Creek the limestone ore is shown 210 feet above the level of Blaine. At Mr. Large's, on Blaine, below the mouth of Daniels' Creek, the following section is shown:

Sandstone cliff near top of hill	20 feet.
Shales with kidney ore	30 "
Limestone ore (on surface).	
Shales and shaly sandstone	15 to 20 "
Sandstone, with bands of shale (partly covered) to bed of Blaine	215 "

Both the kidney ore and the limestone ore are exposed in the road leading from Daniels' Creek to the Right Fork of Irish Creek, the latter in a bed a foot or more in thickness under fire-clay. A coal is shown in the branch below, which is probably No. 2, being associated with a thin black silicious band which accompanies Coal No. 2 in this region. Towards the head of Blaine from these points the series rises about 10 feet to the mile for the whole distance, though to the mouth of Cherokee the dip is somewhat less. (See sections on plate 25). The highest hills in this region show the first impure limestone (yellow limestone) near the top. At most points, it is shown at the surface in weathered nodules or rounded blocks of yellowish silicious limestone. It is exposed in the road at the top of the hill between Rich Creek and Little Blaine, where it closely resembles the ferriferous limestone, and might mislead as to the place of the limestone ore. On the Rich Creek side this ore is exposed 75 feet lower down, associated with fire-clay, as in Greenup, Carter, and Boyd. The coals are not exposed here; but near Mr. Berry's, on the road to Haw's Mill, the following order is shown:

Kidney ore at surface, near top of hill.	
Shale and sandstone, mostly covered	50 feet.
Limestone ore.	
Shales	15 "

"Limestone kidney ore."	
Sandstone, shaly in parts	80 feet.
Coal stain (Coal 3).	
Shaly rock	18 "
Slight coal stain (probably local).	
Sandstone, coarse at top, forming cliff	85 "
Coal (not opened) No. 2.	
Sandstone and shales to bed of creek	20 "

The "limestone kidney ore" is the same, both in position and character, as that found in Carter county. It is a grey, somewhat oölitic ore, having a smaller per cent. of iron than the "limestore ore" above; but it is more easily smelted, and is therefore highly prized. Coal 1 is not shown in this section; it would be found 30 feet below the drainage, or about 50 feet below No. 2. The order which is shown in this section is so uniformly preserved over the country drained by the branches of Blaine to the southward, that it is only necessary to point out the place of the ferriferous limestone and ore, and the height above the main drainage, to indicate the economic geology of the several valleys. The "limestone kidney ore" is not always present. It will be noticed that the section is shortened very much, as compared with the same series of rocks in Greenup and Carter. The tendency of the rocks below the ferriferous limestone to thin out towards Lawrence county has been pointed out on a previous page. The fact is well attested on the head waters of Blaine, where all the rocks, from the conglomerate to the ferriferous limestone, are shown in one continuous section, so as to be easily compared with the same series as shown on Deer Creek west of Willard.

On Bushy Creek the ferriferous limestone and ore is shown at a number of places, as in the road over the ridge to the Swetnam settlement, from near the mouth of Bushy, and at the head of Saunders' Branch, 230 to 240 feet above Bushy. On the Blaine side of the ridge it is 10 to 20 feet higher. Along this ridge also the kidney ore, 50 feet above, is regularly present on the surface in such abundance as to indicate a valuable deposit. In quality, this ore is inferior to the limestone ore; but except that it occurs in rounded, kidney-like aggregations, it might easily be mistaken for that ore. No well-attested average could be obtained for analysis. A sam-

ple taken from the ore as exposed at the surface gives the following result:

Peroxide of iron	56.778	Iron 39.744
Alumina	.782	
Lime	trace.	
Magnesia	trace.	
Phosphorus	trace.	
Sulphur	.126	
Combined water	10.516	
Insoluble residue	31.280	Silica 25.60
Total	99.482	

An analysis of the limestone ore, from samples similarly obtained, shows the following result:

Peroxide of iron	68.550	Iron 47.985.
Alumina	.380	
Lime	trace.	
Magnesia	trace.	
Phosphorus	trace.	
Sulphur	.175	
Combined water	10.150	
Insoluble residue	20.480	Silica 16.96.
Total	99.735	

Sections 73, 74, and 75, plate 20, will serve to locate both the coals and the ores on Irish, Cherokee, and Kane's Creeks. Near the head of these creeks the height above drainage of the limestone ore would be reduced somewhat. (See sections 66 and 67, plate 18). A gradual rise is shown towards the head of Blaine. At the mouth of Upper Laurel, a rather rough block ore is shown in the place of the lower block ore of Greenup. Sections 68, plate 18, and 90 and 91, plate 24, although they do not show the upper beds, indicate the height above drainage at which they may be found in the neighboring hills. Section 66 shows the normal position of the coals higher up in the series than those which have been opened in this region. The higher hills generally include the rocks of this series; and doubtless some, perhaps all, of the coals shown in this section would be found in such relation to the limestone ore as is here shown. No effort has been made to open these coals, so that little can be said as to the thickness or quality of these beds. They are Nos. 5, 6, and 7, of the general section. The geology of the valley of Little Blaine is similar to that of the region just considered. The details have not been so fully

worked out, however, and a fuller report will be deferred to be presented with that of George's Creek and of that part of Lawrence county which lies between the forks of Big Sandy river, which, for reasons already given, will be connected with Martin and Johnson counties in a future report.

GENERAL REMARKS.

The irregularities of the dip of the coal-measure rocks in this part of Kentucky has heretofore been the occasion of a good deal of misapprehension as to the equivalency of the coals, and of the stratification of the country generally. It has, therefore, been necessary to undertake a more careful study of this field than had previously been made: 1st, to make out the real stratification, and to establish from it a natural classification of beds; and 2d, to recognize the dip of the strata, as determining the distribution and also the local position of the beds. The first object has been in a large measure, if not fully, accomplished for this region, giving the true succession of beds in the whole series, and also what is of no less importance, giving a key to the coal measures further back from the Ohio. The second object has also been reached so far as to show the general range of beds, and to point out the most of their irregularities of dip which affect the local position of beds. As the topographical features of this region are more or less related to the facts which have been established in respect to the dip of the rocks, a more connected statement of the varying dip, and its relation to the drainage system of the country, may be found both interesting and useful. The accompanying map diagram will present this so as to be readily understood by every one. The steepness of the dip is represented approximately, and the variation, both in degree of inclination and in direction, is given in sufficient detail for the purpose intended. Many minor variations or undulations of the strata, which occur as waves, both parallel with the dip and interrupting it, are omitted as unimportant. West of Tygert's Creek the inclination of the top of the Waverly is followed. The overlying rocks (sub-carboniferous

limestone and coal-measure rocks) would present a less uniform eastward dip, for reasons which have been given in connection with the geology of this valley. East of Tygert's Creek the inclination of the regular beds of coal and ore is represented. It will be seen that the changes in dip in this region are frequent and well-marked, representing local upheavals and depressions which are the accompanying effects of the grander upheavals to the southeast. Few indications of faults or dislocations of strata are found in this region. It is not unlikely, however, that local faults may exist in the regions which present the strongest evidences of disturbing forces.

THICKNESS OF WORKABLE COALS.

Nearly all of the beds of coal which have been found in this part of Eastern Kentucky are, at some points, of a workable thickness; some of them are rarely too thin to be worked profitably. The following table gives a general view of the beds as they appear from what is now known of them. The thickness is such as appears from openings already made. The areas include so much of the country as is within the line of outcrop of each bed. The actual area of the beds above drainage is reduced at least one half by the excavations of the valleys. The area below the main drainage is given as though each bed were continuous throughout, from the line where it falls below the drainage. No sufficient data is available for making up a decided opinion on this point. Quite a number of bored wells have been sunk in this region, but no reliable record has been found of any of them.

TABULAR VIEW OF COALS, &c.

Greenup County.

Coals	1	2	3	4	5	6	7	8	9	10	11	Total thickness.
Greatest thickness—inches	36	30	60	50	?	54	36	.	. .	. .	. .	22 feet.
Ordinary thickness	24	20	36	30	?	36	36	.	. .	. .	. .	15 feet.
Area of territory—square miles	340	300	215	175	110	60	30	.	. .	. .	. .	. . . . .
Area below the main drainage	65	47	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .
Average thickness of intervening rocks		90	100	35	100		40	. .	. .	. .	. .	. . . . .
Iron ores included	2	1	1	1	2		1	. .	. .	. .	. .	. . . . .

Carter County.

	1	2	3	4	5	6	7	8	9	10	11	Total thickness.
Greatest thickness—inches	50	37	40	?	72	24	60	55	24	. .	. .	30 feet.
Ordinary thickness	30	20	30	?	?	20	36	36	20	. .	. .	16 feet.
Area of territory	360	315	276	270	140	132	76	68	60	. .	. .	. . . . .
Area below drainage	98	85	62	57	49	40	30	13	9	. .	. .	. . . . .
Average thickness of intervening rocks	.	50	100	70		50	43	55	35	.	. .	. . . . .
Iron ores included	1	1	1	1		2	1	1	. .	. .	. .	. . . . .

Boyd County.

	1	2	3	4	5	6	7	8	9	10	11	Total thickness.
Greatest thickness—inches	.	. .	35	30	40	40	72	48	25	.	.	24½ feet.
Average thickness	. .	. .	30	?	28	38	52	30	20	.	.	16 feet.
Area of territory	169	169	160	160	160	100	160	158	155	. .		. . . . .
Area below drainage	169	169	160	157	135	100	60	32	25	.		. . . . .
Average thickness of intervening rocks	. .	. .	30	50	40	40	45	35	.	.		. . . . .
Iron ores included	. .	. .	1			1	1	1	1	1	.	. . . .

Lawrence County.

	1	2	3	4	5	6	7	8	9	10	11	Total thickness.
Greatest thickness—inches	36	20	73	. .	84	46	36	40	. .	30	43	34 feet.
Ordinary thickness	30	20	36	. .	36	24	30	36	?	?	?	17½ feet.
Area of territory	386	386	386	. .	386	356	320	285	250	175	140	. . . .
Area below drainage	210	180	164	. .	80	50	42	25	10	. .	. .	. . . .
Average thickness of intervening rocks		50	100	65		45	35	40	35	75	45	. . . . .
Iron ores included	. . .		1	. .		2	. .	1	. .	. .	1	. . . .
Cannel coals	. .	. .	. .	*	.	.	.	. .	. .	*	. .	. . . .
Beds changed to cannel at some points	. .	*	*	.	. .	*	. .	*	. .	. .	. .	. . . .

SOILS.

The soils of Eastern Kentucky are such as might be inferred from the character of the rocks which have been described in the foregoing reports. The soils of the whole region are of medium fertility, varying in character from clayey to sandy

loam, with the successive rock formations, as observed in traveling eastward over this region. The distinct character of the soils, as derived from special formations, is rarely preserved, the height of the hills being great enough generally to include two or more distinct formations. The precise relation of the rock formation to the soil is not shown, therefore, either by the characters which appeal to the eye, or by analyses made as a test of fertility. There is, however, a general relation shown by the predominance of successive formations in the valleys eastward from Rowan and Lewis counties. The traveler, passing from west to east over the country, will readily detect the changes in the appearance of the soil, as well as in the topography of the country, as the different formations predominate in the hills along the way. West of the Tygert's Creek valley the Waverly sandstone and shales make up nearly the whole height of the hills, and the soil is readily recognized as derived from the Waverly Group. It is of a light brick color, shaded somewhat with the characteristic olive-green of this formation. The sand is fine, and the proportion of clay is large. The topography of this belt is equally well-marked; the hills rising rather abruptly from the flat creek bottoms in well-rounded knob-like forms. The outcrop of the conglomerate sandstone frequently forms an escarpment at the top of these hills, which, in a general way, marks the base of the coal measures.

In the greater part of the Tygert's Creek valley the subcarboniferous limestone and the conglomerate sandstone give character to the soil; a large proportion of coarse sand being seen in the soil, while an analysis shows an increased proportion of lime, potash, and soda. The outlines of the hills are equally characteristic of these formations, which give rise to the rugged cliffs and the wild scenery of the Tygert's Creek belt.

In the Little Sandy valley the soil is derived mostly from the coal-measure rocks, and, except near the head of the river, from the rocks above the conglomerate. The sandstones and shales of the coal measures give rise to sandy or clayey loam, accordingly as the former or the latter predominates in any

given section. The shales next above the conglomerate sandstone give a fine clayey loam, as shown at many points in the valley of the Little Sandy, and on the head waters of Blaine and George's Creeks. The sandstone series gives rise to a sandy soil, often deeply colored with oxide of iron, as in the Flat Woods region near Ashland; while the greenish shale series above resembles in its soil the Waverly Group, but with a larger per cent. of iron, as shown by the deeper shade of red.

The Chatterawha or Big Sandy valley, from its geological features, has a larger proportion of coarse sandy soil, though at many points the red and greenish shales above the Mahoning sandstone become prominent, giving rise to a red loam, as seen around Louisa, in Lawrence county.

The following table of analyses, by Dr. Peter and Mr. Talbutt, shows the properties of the soil at a number of localities, which may be regarded as representative for the different belts of country, as marked out by the geological features of this region:

TABLE OF ANALYSES OF SOILS OF EASTERN KENTUCKY.

	West of Garvin's Hill, Carter co. Creek bottom; old field.		*West of Garvin's Hill, Carter county, 55 feet above the creek; old field.*		*West of Garvin's Hill, Carter co., 115 feet above creek; woods.*		*Three miles east of Olive Hill, Carter county. Old pasture; 50 feet above creek.*		*Pea Ridge, Greenup co. Woodland; near top of ridge.*		*Near Cannonsburg, Boyd co. East Fork bottom; old field.*		*Near Cannonsburg, Boyd co. East Fork bottom; woodland.*		*Near Cannonsburg, Boyd co. Hillside; woodland.*	
	WAVERLY FORMATION		WAVERLY FORMATION.		WAVERLY FORMATION.		SUB-CARB. FORMATION.		HORIZON OF COAL NO. 6.		HORIZON OF COAL NO. 5.		HORIZON OF COAL NO. 5.		HORIZON OF COAL NO 8.	
	Top soil	Sub soil.	Top soil	Sub-soil.	Top soil	Sub-soil.	Top soil	Sub-soil.	Top soil	Sub-soil.	Top soil	Sub-soil.	Top soil	Sub-soil.	Top soil	Sub-soil.
Sand and insoluble silicates	89.390	91.215	91.240	91.575	89.515	89.940	91.690	90.515	86.505	84.565	83.765	83.385	90.490	88.420	81.410	83.230
Soluble silicates	.220	.120	.202	.020	. . . .	. . . .	. . .	.145	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .
Alumina, oxides iron and manganese	6.115	5.600	4.540	5.890	4.013	5.410	4.777	6.409	6.831	9.595	9.019	9.675	5.091	6.642	7.425	9.984
Carbonate of lime	.245	.220	.145	.080	.109	.109	.880	.680	a trace.	.123	.259	.276	214	.116	.571	.392
Magnesia	.115	.178	.035	.056	.050	.061	.057	.155	.116	.223	.333	.053	.034	.178	.352	.251
Potash	.279	.366	.111	.204	.153	.371	.213	.255	.217	.231	.344	.282	.317	.307	.435	.205
Soda	.286	.048	.157	.131	.032	.046	.132	.151	.055	.097	.027	.176	.076	.099	.045	.050
Phosphoric acid	.076	.086	.125	.163	.147	.163	.093	.076	.089	.115	.150	.161	.134	083	.208	.191
Sulphuric acid	not est.	not est.	not est.	not est.	.060	.046	. . . .	. . . .	.058	.017	.038	a trace.	a trace.	a trace.	a trace.	a trace.
Organic and volatile matters	3.740	2.200	2.860	2.000	4.685	2.625	2.250	1.815	5.056	4.030	4.915	4.905	3.140	3.085	7.985	5.190
Water	.828	450	.690	.450	.990	.720	.600	.480	1.000	.685	1.235	1.315	.656	525	.915	.500

PLATE NO.1

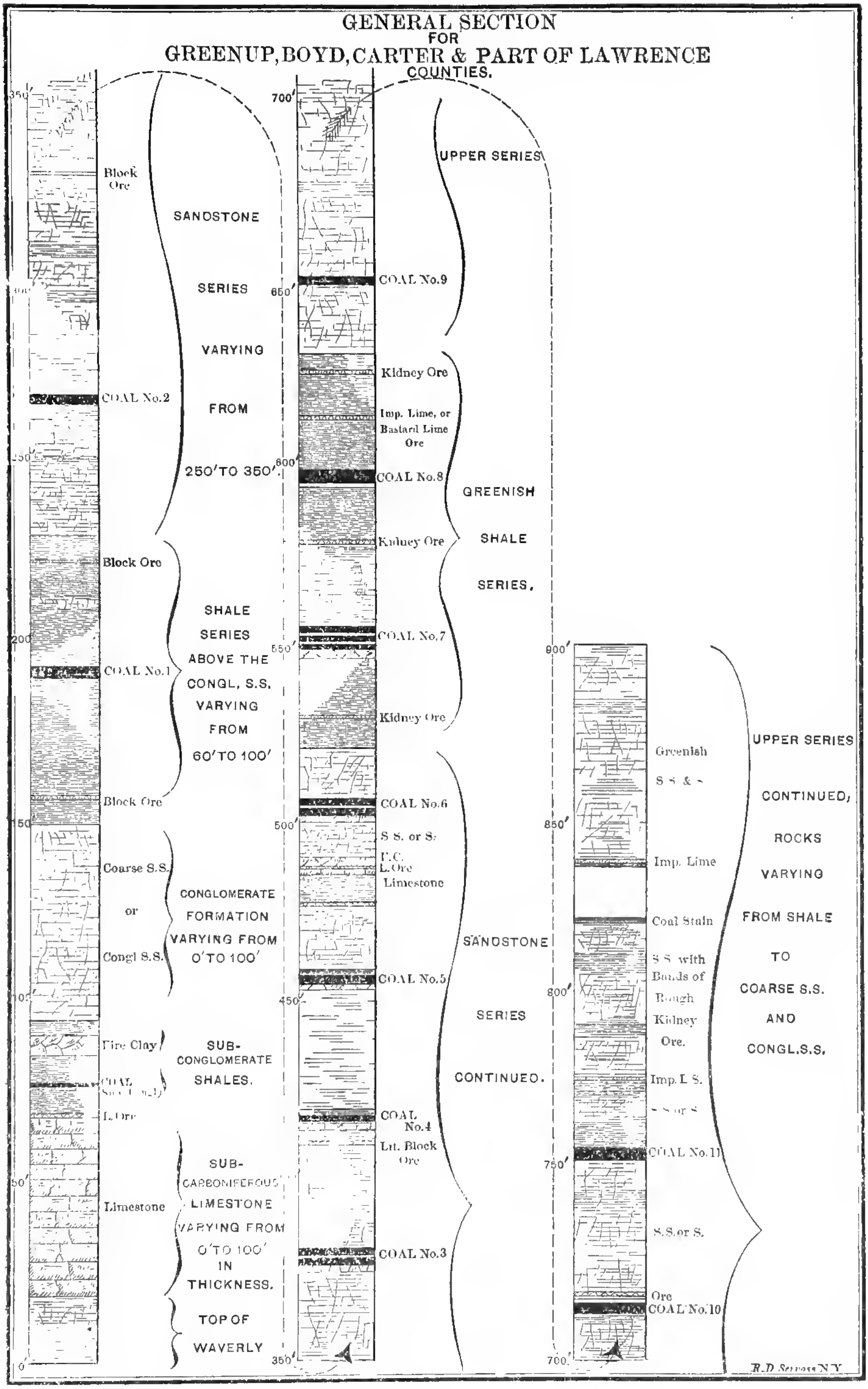
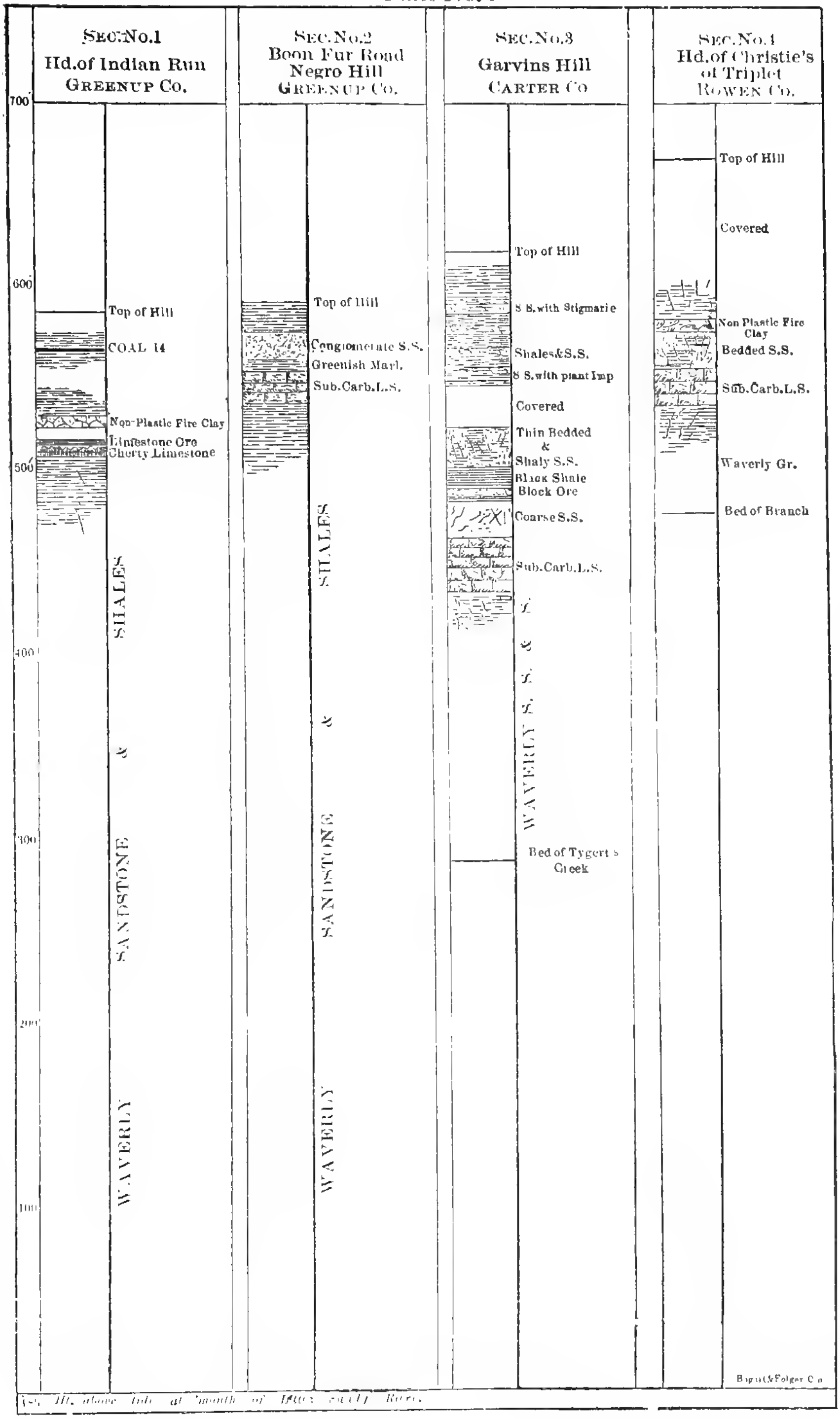
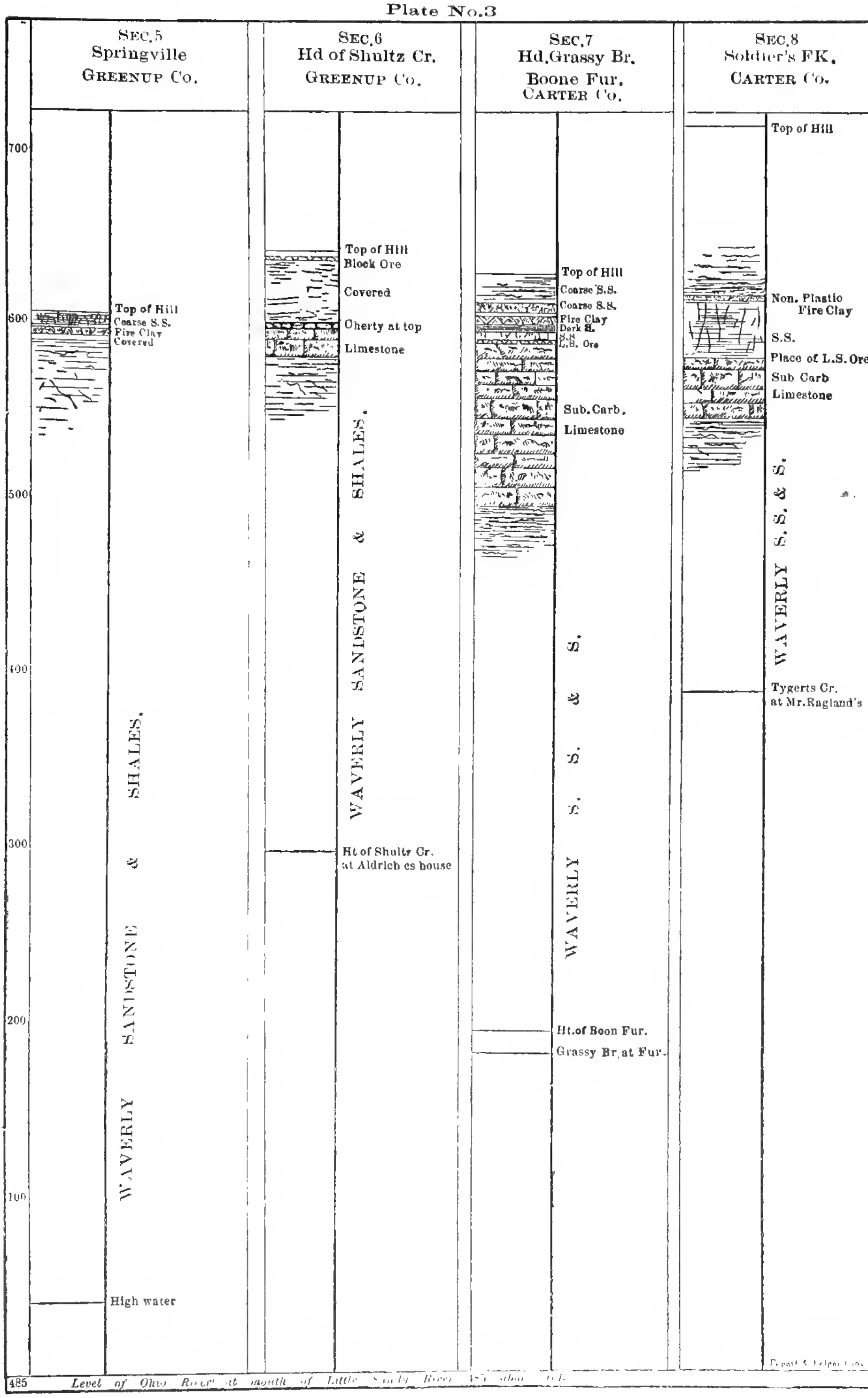

GENERAL SECTION
FOR
GREENUP, BOYD, CARTER & PART OF LAWRENCE
COUNTIES.
350′
Block Ore
SANDSTONE
SERIES
VARYING
FROM
250′ TO 350′.
COAL No.2
250
Block Ore
200
COAL No.1
SHALE
SERIES
ABOVE THE
CONGL, S.S.
VARYING
FROM
60′ TO 100′
Block Ore
150
Coarse S.S.
or
Congl S.S.
CONGLOMERATE
FORMATION
VARYING FROM
0′ TO 100′
Fire Clay
SUB-
CONGLOMERATE
SHALES.
Limestone
SUB-
CARBONIFEROUS
LIMESTONE
VARYING FROM
0′ TO 100′
IN
THICKNESS.
TOP OF
WAVERLY
0
700′
UPPER SERIES
COAL No.9
650′
Kidney Ore
Imp. Lime, or
Bastard Lime
Ore
600′
COAL No.8
GREENISH
SHALE
SERIES,
Kidney Ore
COAL No.7
550′
Kidney Ore
COAL No.6
500′
S S. or S.
SANDSTONE
SERIES
CONTINUED.
Limestone
COAL No.5
450′
COAL
No.4
Lit. Block
Ore
COAL No.3
350′
900′
Greenish
850′
Imp. Lime
Coal Stain
800′
Kidney
Ore.
Imp. L S.
COAL No.11
750′
S.S.or S.
Ore
COAL No.10
700′
UPPER SERIES
CONTINUED,
ROCKS
VARYING
FROM SHALE
TO
COARSE S.S.
AND
CONGL.S.S.

Plate No. 3



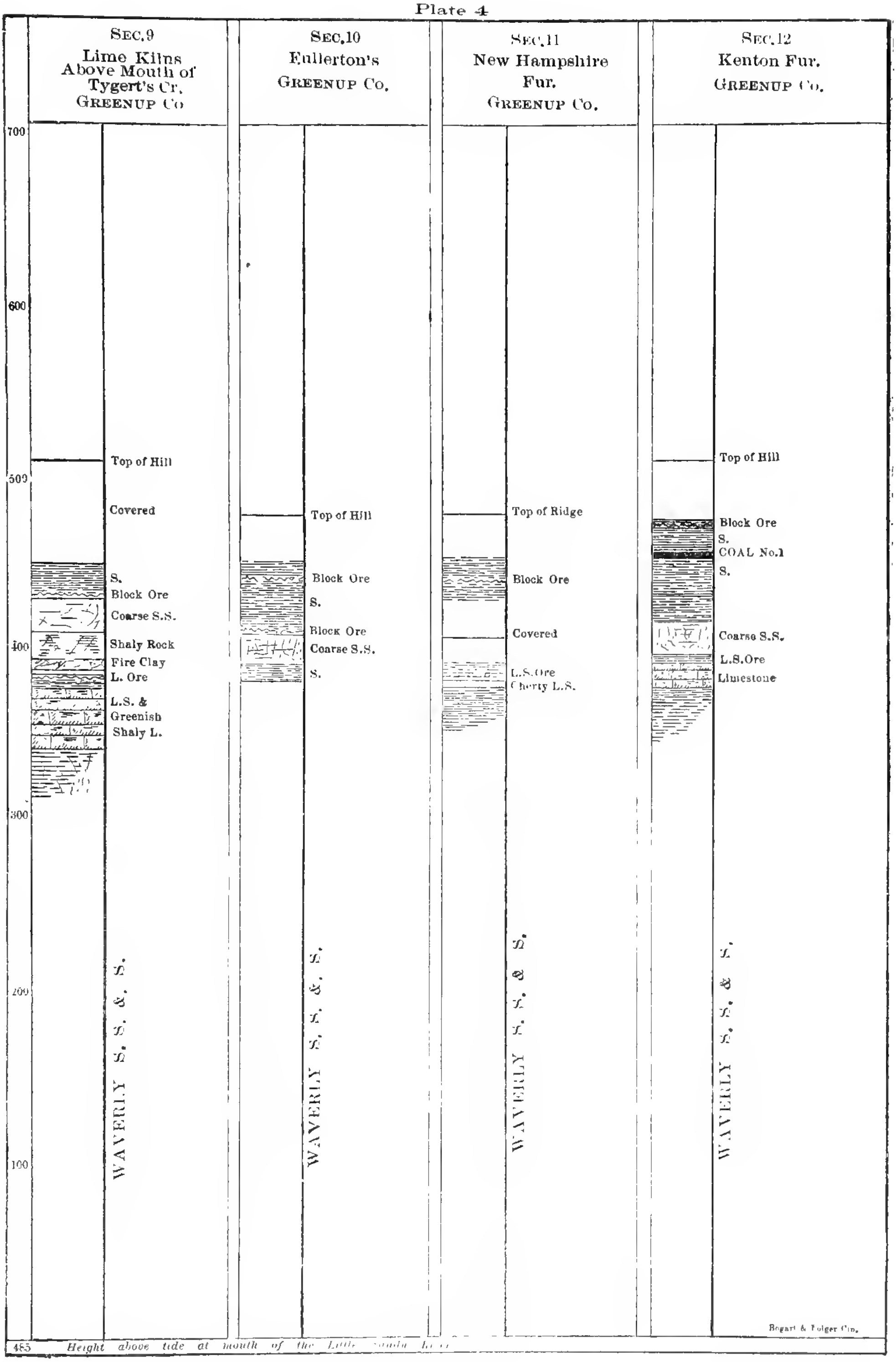
SEC. No. 1
Hd. of Indian Run
GREENUP Co.
SEC. No. 2
Boon Fur Road
Negro Hill
GREENUP Co.
SEC. No. 3
Garvins Hill
CARTER Co.
SEC. No. 4
Hd. of Christie's
of Triplet
ROWEN Co.
700
600
500
400
300
200
100
Top of Hill
COAL 14
Non-Plastic Fire Clay
Limestone Ore
Cherty Limestone
SHALES
&
SANDSTONE
WAVERLY
Top of Hill
Conglomerate S.S.
Greenish Marl.
Sub.Carb.L.S.
SHALES
&
SANDSTONE
WAVERLY
Top of Hill
S S. with Stigmarie
Shales & S.S.
S S. with plant Imp
Covered
Thin Bedded
&
Shaly S.S.
Black Shale
Block Ore
Coarse S.S.
Sub.Carb.L.S.
WAVERLY
Bed of Tygert's
Creek
Top of Hill
Covered
Non Plastic Fire
Clay
Bedded S.S.
Sub.Carb.L.S.
Waverly Gr.
Bed of Branch
Bien & Folger Co.

Plate No.3



SEC.5
Springville
GREENUP Co.
Top of Hill
Coarse S.S.
Fire Clay
Covered
WAVERLY SANDSTONE & SHALES.
High water
SEC.6
Hd of Shultz Cr.
GREENUP Co.
Top of Hill
Block Ore
Covered
Cherty at top
Limestone
WAVERLY SANDSTONE & SHALES.
Ht of Shultz Cr.
at Aldrich es house
SEC.7
Hd.Grassy Br.
Boone Fur.
CARTER Co.
Top of Hill
Coarse S.S.
Coarse S.S.
Fire Clay
Dark S.
L.S. Ore
Sub.Carb.
Limestone
WAVERLY S. S. & S.
Ht.of Boon Fur.
Grassy Br.at Fur.
SEC.8
Soldier's FK.
CARTER Co.
Top of Hill
Non. Plastic
Fire Clay
S.S.
Place of L.S.Ore
Sub Carb
Limestone
WAVERLY S. S. & S.
Tygerts Cr.
at Mr.Ragland's
700
600
500
400
300
200
100
485
Level of Ohio River at mouth of Little Sandy River

Plate 4



Height above tide at mouth of the Little Sandy River

Plate 5

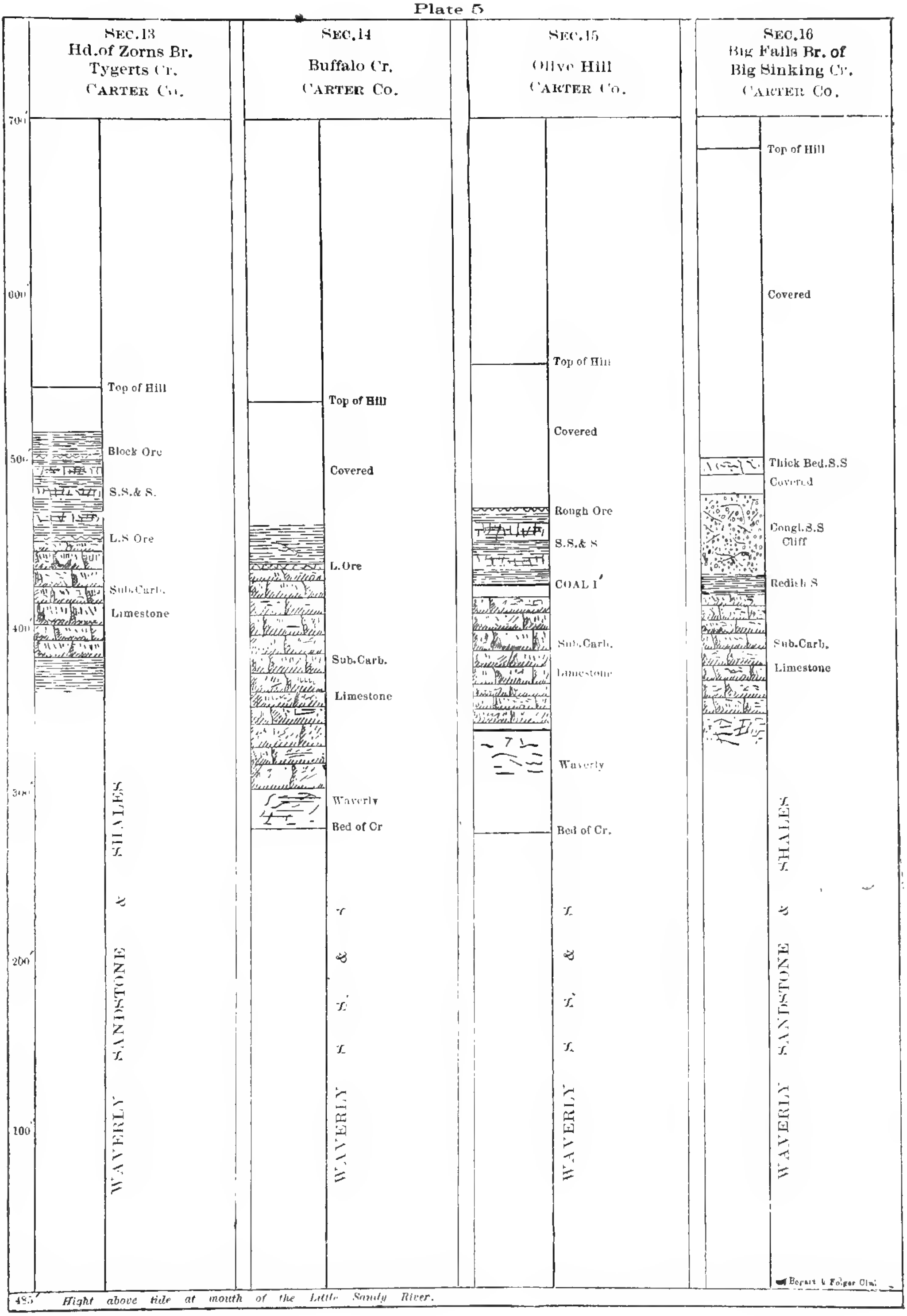
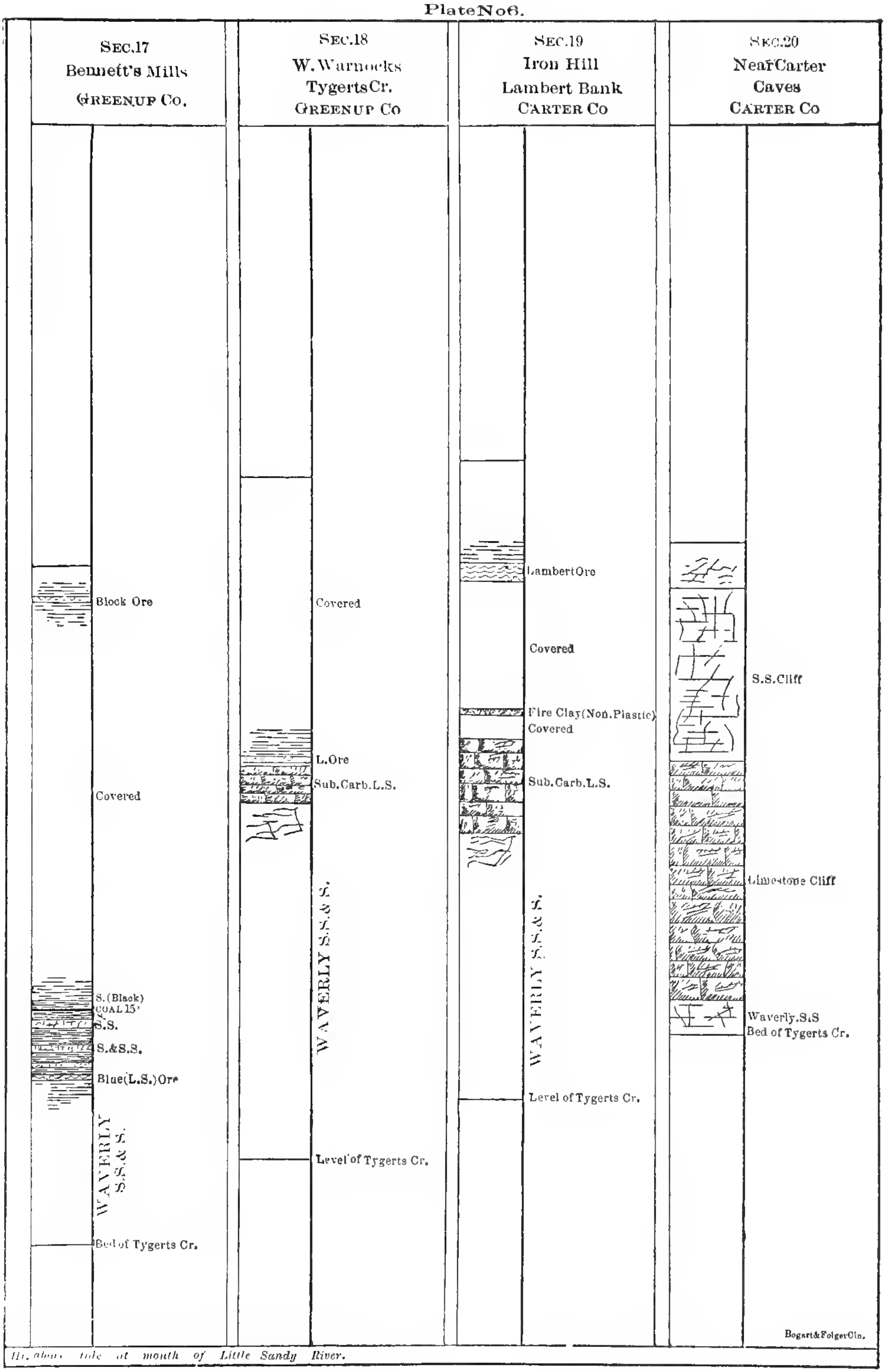
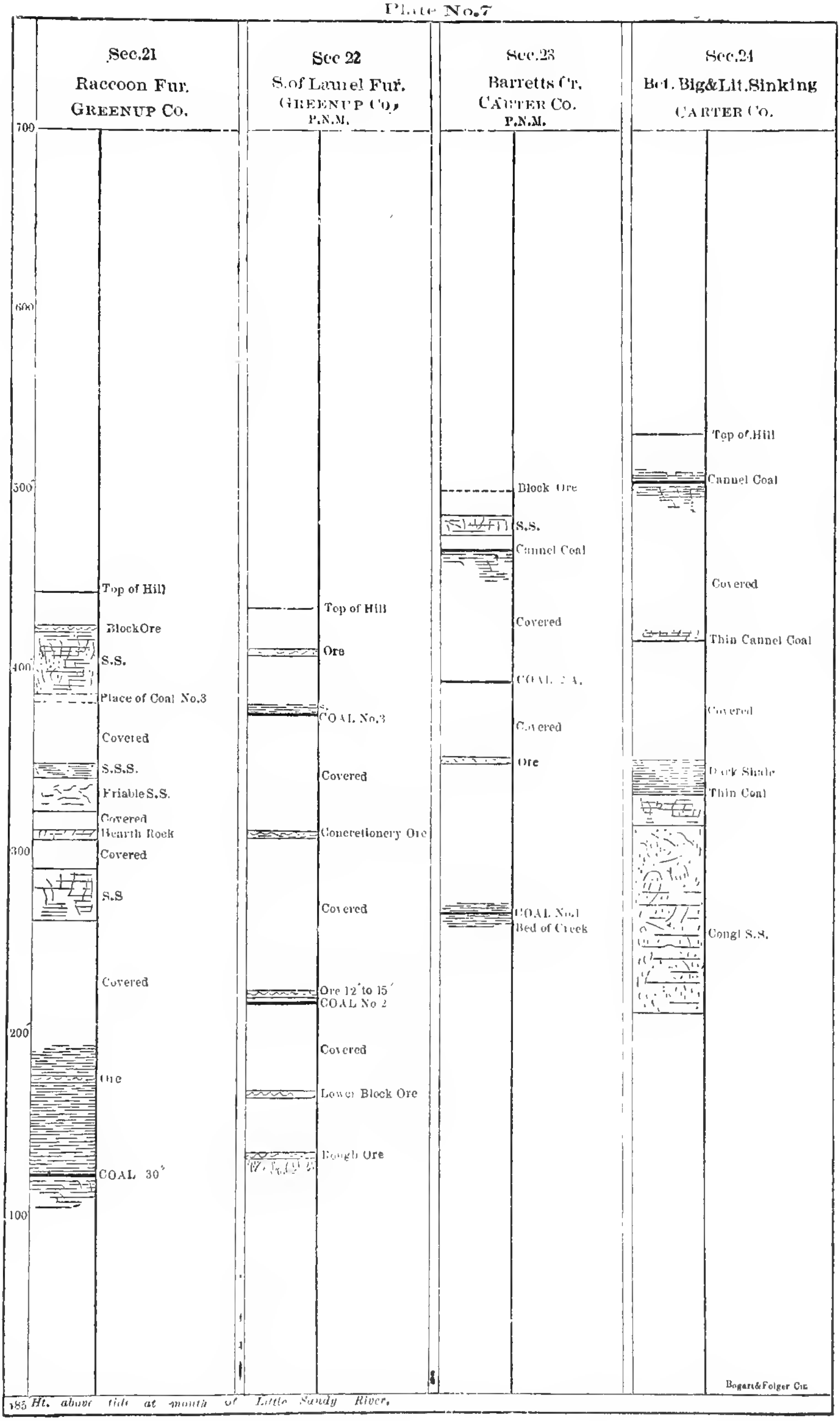

SEC. 13
Hd. of Zorns Br.
Tygerts Cr.
CARTER Co.
SEC. 14
Buffalo Cr.
CARTER Co.
SEC. 15
Olive Hill
CARTER Co.
SEC. 16
Big Falls Br. of
Big Sinking Cr.
CARTER Co.
700'
600'
500'
400'
300'
200'
100'
485'
Top of Hill
Block Ore
S.S. & S.
L.S Ore
Sub.Carb.
Limestone
WAVERLY SANDSTONE & SHALES
Top of Hill
Covered
L. Ore
Sub.Carb.
Limestone
Waverly
Bed of Cr
WAVERLY S. & S.
Top of Hill
Covered
Rough Ore
S.S. & S
COAL I
Sub.Carb.
Limestone
Waverly
Bed of Cr.
WAVERLY S. & S.
Top of Hill
Covered
Thick Bed. S.S
Covered
Congl. S.S
Cliff
Redish S
Sub.Carb.
Limestone
WAVERLY SANDSTONE & SHALES
Bogart & Folger Clai
Hight above tide at mouth of the Little Sandy River.

Plate No 6.



Sec. 17
Bennett's Mills
Greenup Co.
Block Ore
Covered
S. (Black)
COAL 15'
S.S.
S.&S.S.
Blue (L.S.) Ore
WAVERLY S.S.&S.
Bed of Tygerts Cr.
Sec. 18
W. Warnocks
Tygerts Cr.
Greenup Co
Covered
L. Ore
Sub. Carb. L.S.
WAVERLY S.S.&S.
Level of Tygerts Cr.
Sec. 19
Iron Hill
Lambert Bank
Carter Co
Lambert Ore
Covered
Fire Clay (Non. Plastic)
Covered
Sub. Carb. L.S.
WAVERLY S.S.&S.
Level of Tygerts Cr.
Sec. 20
Near Carter
Caves
Carter Co
S.S. Cliff
Limestone Cliff
Waverly. S.S
Bed of Tygerts Cr.
Bogart & Folger Cin.
Ht. above tide at mouth of Little Sandy River.

Plate No.7



Sec.21
Raccoon Fur.
GREENUP Co.
Sec 22
S.of Laurel Fur.
GREENUP Co.
P.N.M.
Sec.23
Barretts Cr.
CARTER Co.
P.N.M.
Sec.24
Bet. Big&Lit.Sinking
CARTER Co.
700
600
500
400
300
200
100
Top of Hill
Block Ore
S.S.
Place of Coal No.3
Covered
S.S.S.
Friable S.S.
Covered
Hearth Rock
Covered
S.S
Covered
Ore
COAL 30"
Top of Hill
Ore
COAL No.3
Covered
Concretionery Ore
Covered
Ore 12" to 15"
COAL No 2
Covered
Lower Block Ore
Rough Ore
Block Ore
S.S.
Cannel Coal
Covered
COAL 2 A.
Covered
Ore
COAL No.1
Bed of Creek
Top of Hill
Cannel Coal
Covered
Thin Cannel Coal
Covered
Dark Shale
Thin Coal
Congl S.S.
Bogart&Folger Cin.
185 Ht. above tide at mouth of Little Sandy River.

Plate No. 8

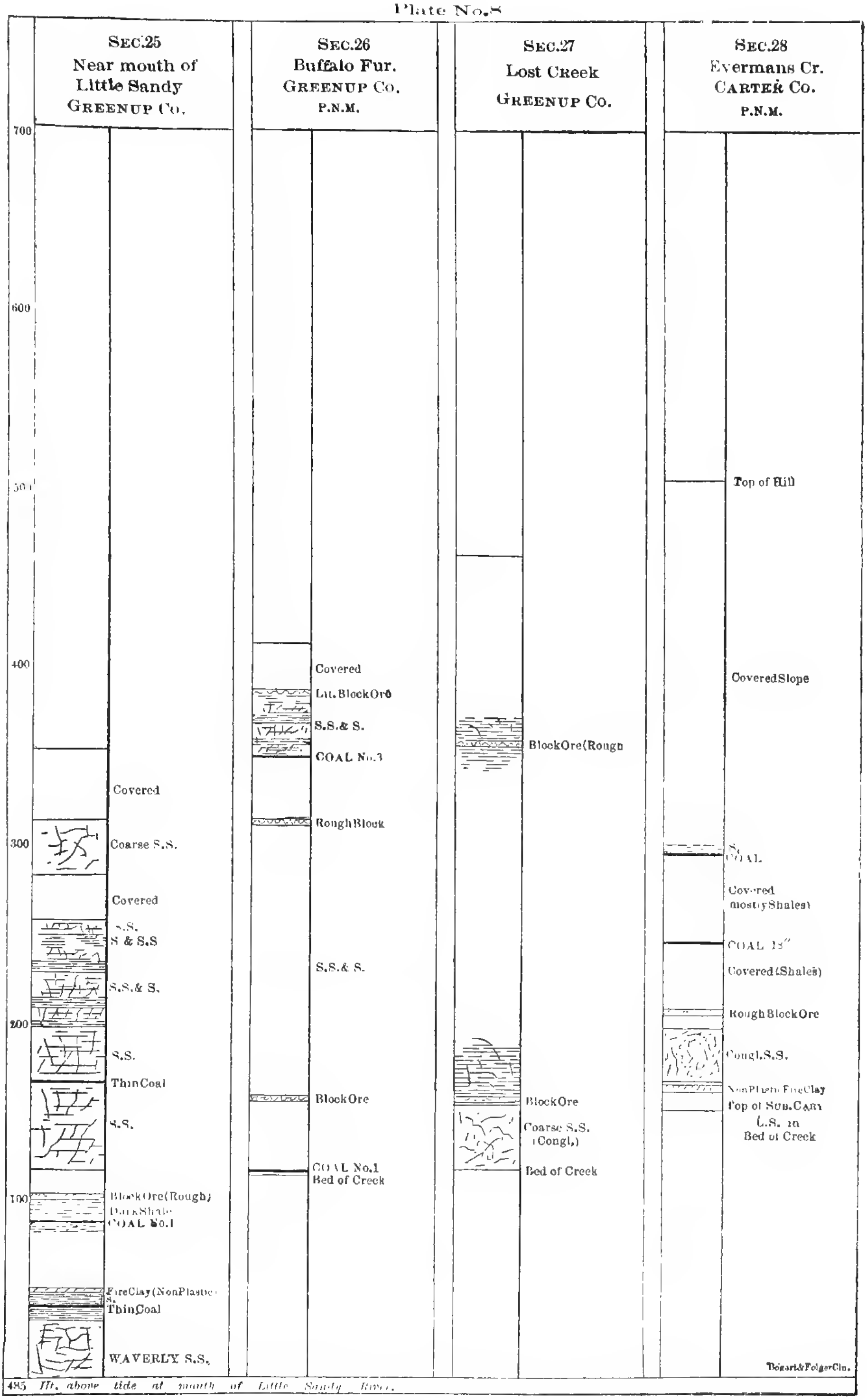
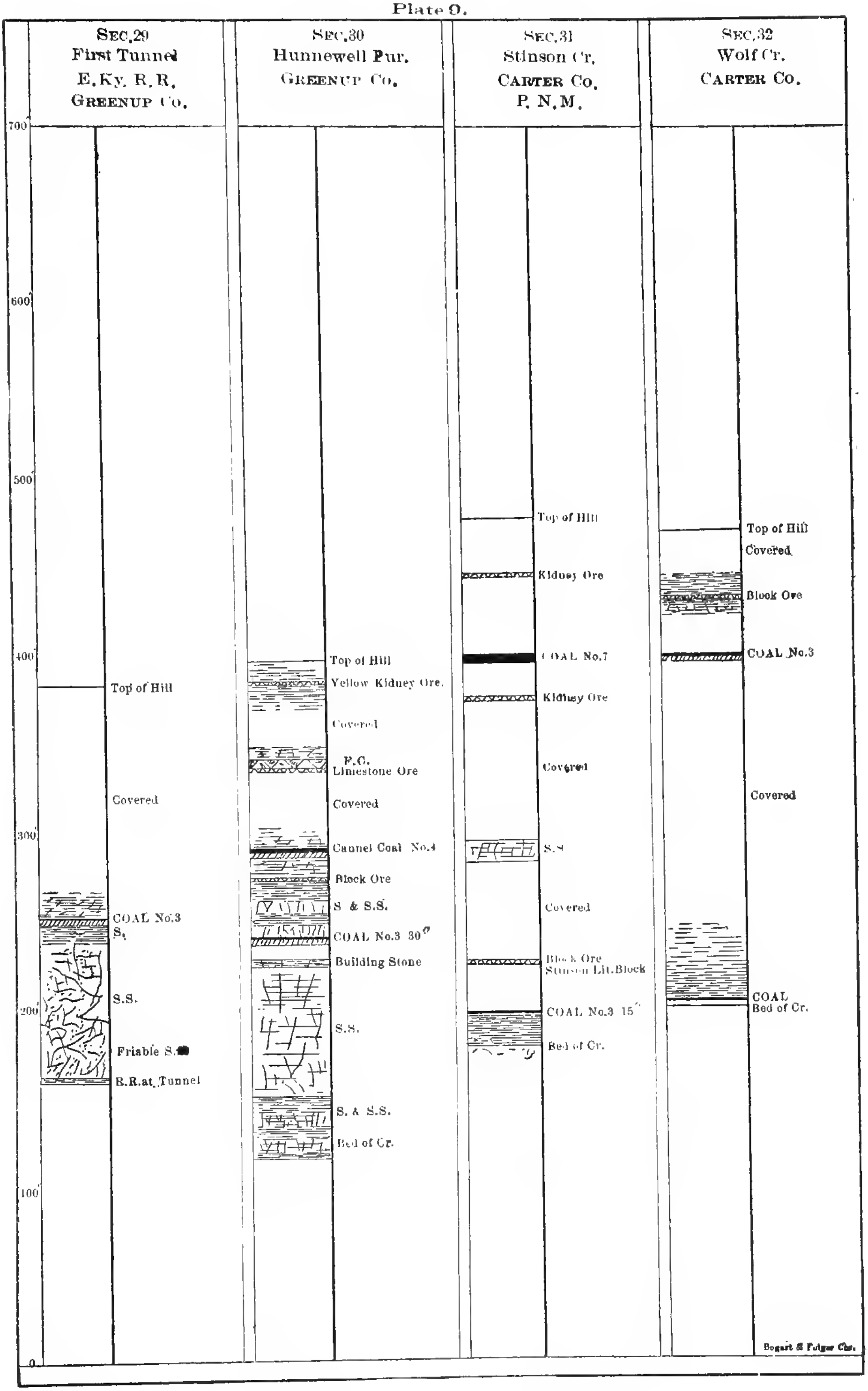

SEC. 25
Near mouth of
Little Sandy
GREENUP CO.
SEC. 26
Buffalo Fur.
GREENUP CO.
P.N.M.
SEC. 27
Lost Creek
GREENUP CO.
SEC. 28
Evermans Cr.
CARTER CO.
P.N.M.
700
600
500
400
300
200
100
Covered
Coarse S.S.
Covered
S.S.
S & S.S
S.S. & S.
S.S.
Thin Coal
S.S.
Block Ore (Rough)
Dark Shale
COAL No. 1
Fire Clay (Non Plastic)
S.
Thin Coal
WAVERLY S.S.
Covered
Lit. Block Ore
S.S. & S.
COAL No. 3
Rough Block
S.S. & S.
Block Ore
COAL No. 1
Bed of Creek
Block Ore (Rough
Block Ore
Coarse S.S.
(Congl.)
Bed of Creek
Top of Hill
Covered Slope
S.
COAL
Covered
(mostly Shales)
COAL 18"
Covered (Shales)
Rough Block Ore
Congl. S.S.
Non Plastic Fire Clay
Top of SUB. CARB.
L.S. in
Bed of Creek
Bogart & Folger Cin.
485 Ht. above tide at mouth of Little Sandy River.

Plate 9.



Sec. 29
First Tunnel
E. Ky. R. R.
Greenup Co.
Sec. 30
Hunnewell Fur.
Greenup Co.
Sec. 31
Stinson Cr.
Carter Co.
P. N. M.
Sec. 32
Wolf Cr.
Carter Co.
700
600
500
400
300
200
100
0
Top of Hill
Covered
COAL No. 3
S.
S.S.
Friable S.
B.R. at Tunnel
Top of Hill
Yellow Kidney Ore.
Covered
F.C.
Limestone Ore
Covered
Cannel Coal No. 4
Block Ore
S & S.S.
COAL No. 3 30"
Building Stone
S.S.
S. & S.S.
Bed of Cr.
Top of Hill
Kidney Ore
COAL No. 7
Kidney Ore
Covered
S.S.
Covered
Block Ore
Stinson Lit. Block
COAL No. 3 15"
Bed of Cr.
Top of Hill
Covered
Block Ore
COAL No. 3
Covered
COAL
Bed of Cr.
Bogart & Folger Chi.

Plate No. 10.

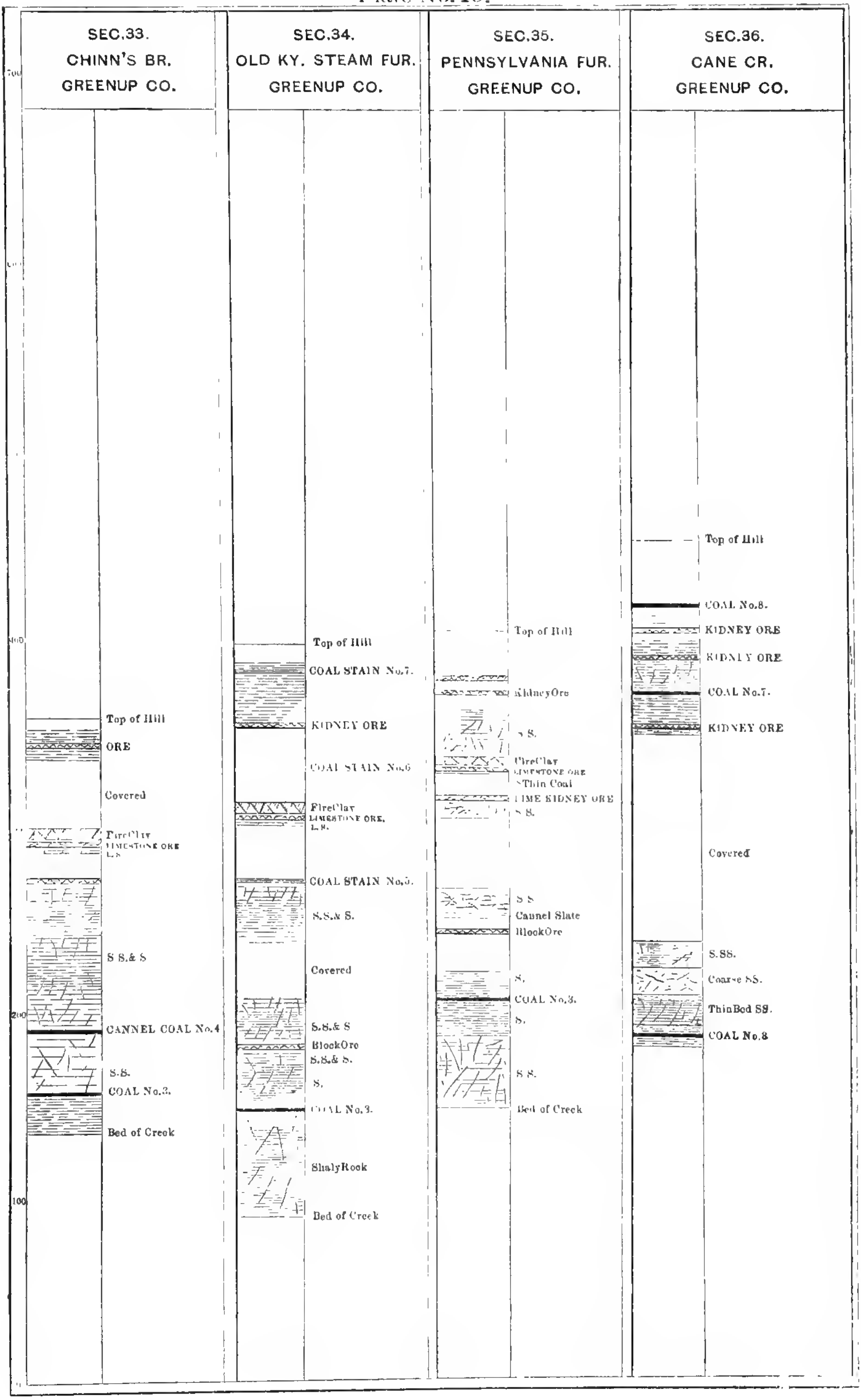

SEC. 33. CHINN'S BR. GREENUP CO.
Top of Hill
ORE
Covered
FireClay
LIMESTONE ORE
S S.& S
CANNEL COAL No.4
S.S.
COAL No.3.
Bed of Creek
SEC. 34. OLD KY. STEAM FUR. GREENUP CO.
Top of Hill
COAL STAIN No.7.
KIDNEY ORE
COAL STAIN No.6
FireClay
LIMESTONE ORE,
L.S.
COAL STAIN No.5.
S.S.& S.
Covered
S.S.& S
BlockOre
S.S.& S.
S.
COAL No.3.
ShalyRock
Bed of Creek
SEC. 35. PENNSYLVANIA FUR. GREENUP CO.
Top of Hill
KidneyOre
S S.
FireClay
LIMESTONE ORE
Thin Coal
LIME KIDNEY ORE
S S.
S S
Cannel Slate
BlockOre
S.
COAL No.3.
S.
S S.
Bed of Creek
SEC. 36. CANE CR. GREENUP CO.
Top of Hill
COAL No.8.
KIDNEY ORE
KIDNEY ORE
COAL No.7.
KIDNEY ORE
Covered
S.SS.
Coarse SS.
ThinBed SS.
COAL No.8
400
200
100

Plate No. 11

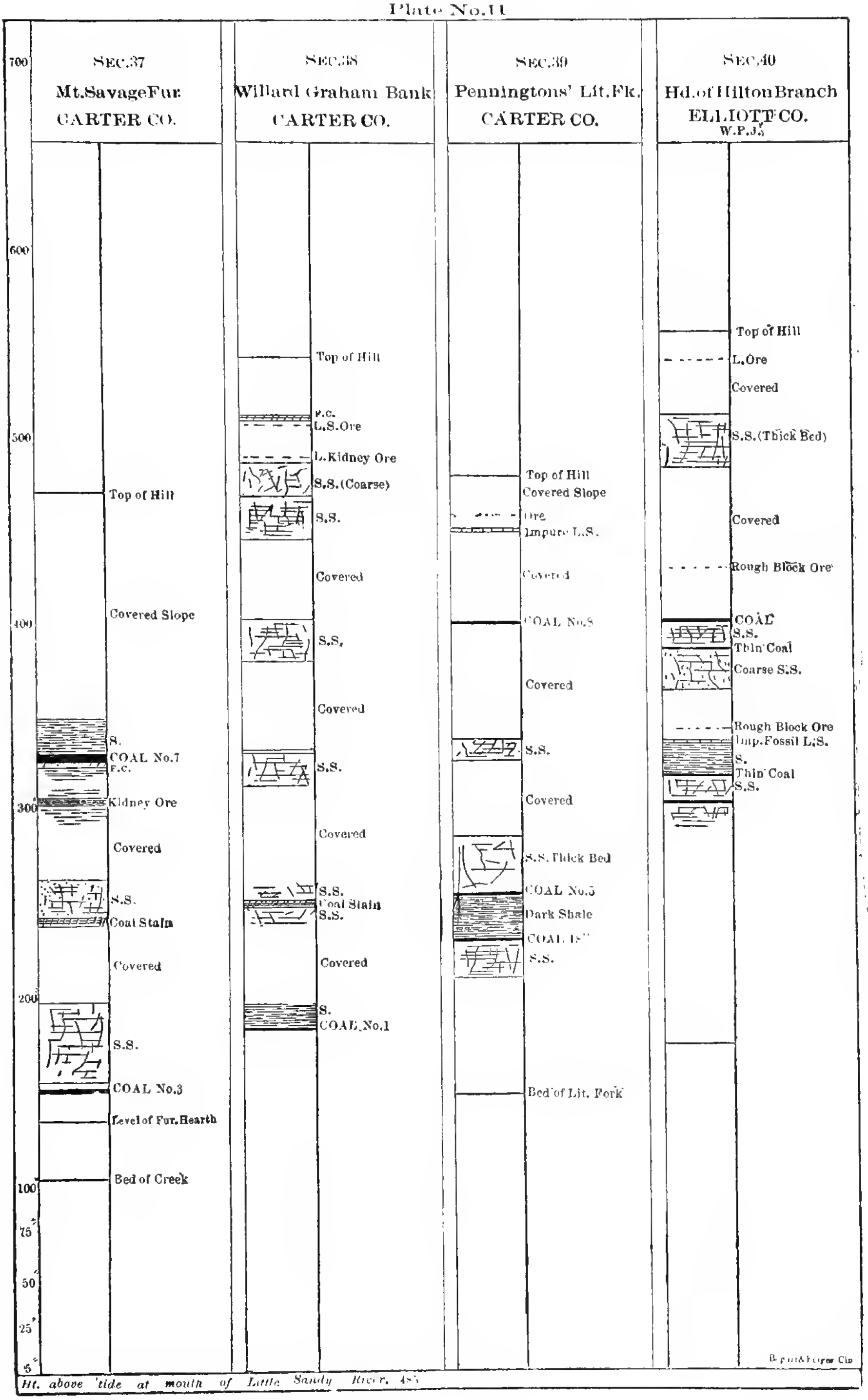
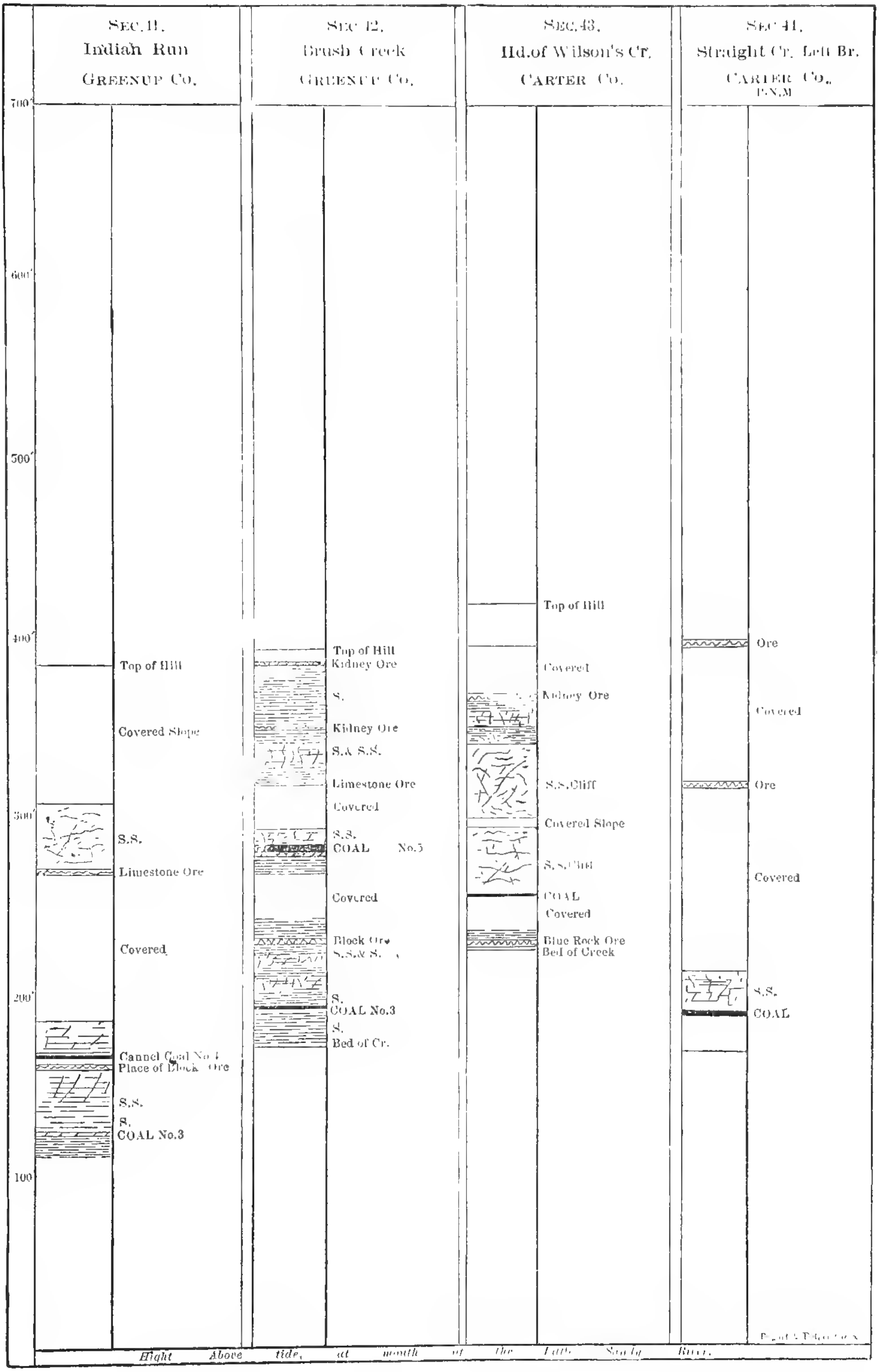

SEC. 37
Mt. Savage Fur.
CARTER CO.
SEC. 38
Willard Graham Bank
CARTER CO.
SEC. 39
Penningtons' Lit. Fk.
CARTER CO.
SEC. 40
Hd. of Hilton Branch
ELLIOTT CO.
W.P.J.S.
700
600
500
400
300
200
100
75
50
25
5
Top of Hill
Covered Slope
S.
COAL No.7
F.C.
Kidney Ore
Covered
S.S.
Coal Stain
Covered
S.S.
COAL No.3
Level of Fur. Hearth
Bed of Creek
Top of Hill
F.C.
L.S. Ore
L. Kidney Ore
S.S. (Coarse)
S.S.
Covered
S.S.
Covered
S.S.
Covered
S.S.
Coal Stain
S.S.
Covered
S.
COAL No.1
Top of Hill
Covered Slope
Ore
Impure L.S.
Covered
COAL No.8
Covered
S.S.
Covered
S.S. Thick Bed
COAL No.5
Dark Shale
COAL 1
S.S.
Bed of Lit. Fork
Top of Hill
L. Ore
Covered
S.S. (Thick Bed)
Covered
Rough Block Ore
COAL
S.S.
Thin Coal
Coarse S.S.
Rough Block Ore
Imp. Fossil L.S.
S.
Thin Coal
S.S.
Ht. above tide at mouth of Little Sandy River, 485

Plate 12.



Sec. 11.
Indian Run
Greenup Co.
Sec. 12.
Brush Creek
Greenup Co.
Sec. 43.
Hd. of Wilson's Cr.
Carter Co.
Sec. 41.
Straight Cr. Left Br.
Carter Co.
700'
600'
500'
400'
300'
200'
100
Top of Hill
Covered Slope
S.S.
Limestone Ore
Covered
Place of Block Ore
S.S.
S.
COAL No.3
Top of Hill
Kidney Ore
S.
Kidney Ore
S.& S.S.
Limestone Ore
Covered
S.S.
COAL No.5
Covered
S.
COAL No.3
S.
Bed of Cr.
Top of Hill
Covered
Kidney Ore
S.S.Cliff
Covered Slope
COAL
Covered
Blue Rock Ore
Bed of Creek
Ore
Covered
Ore
Covered
S.S.
COAL
Hight Above tide, at mouth of the Little Sandy River.

Plate 13

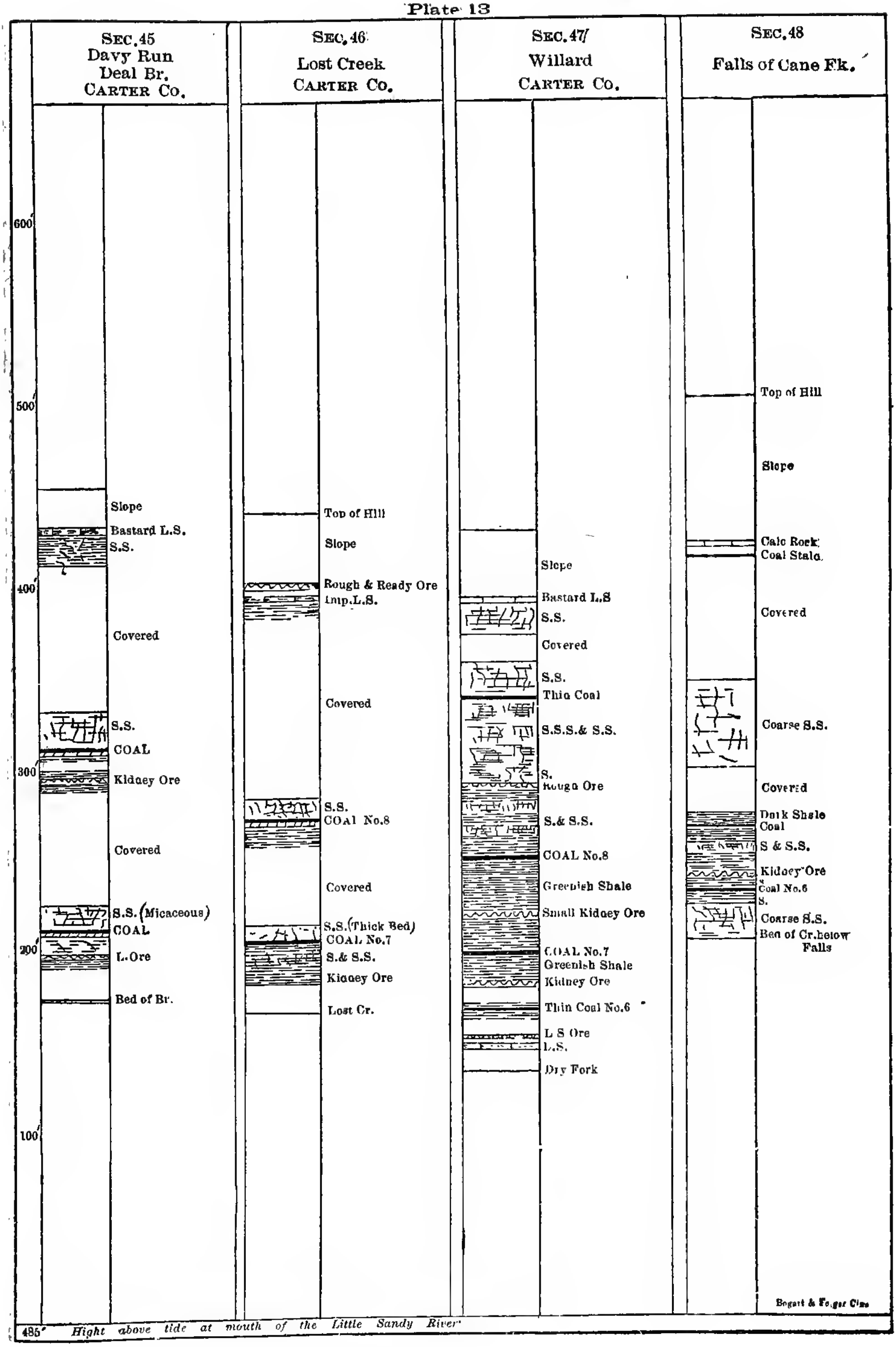

SEC. 45
Davy Run
Deal Br.
CARTER CO.
SEC. 46
Lost Creek
CARTER CO.
SEC. 47
Willard
CARTER CO.
SEC. 48
Falls of Cane Fk.
600'
500'
400'
300'
200'
100'
Slope
Bastard L.S.
S.S.
Covered
S.S.
COAL
Kidney Ore
Covered
S.S. (Micaceous)
COAL
L. Ore
Bed of Br.
Top of Hill
Slope
Rough & Ready Ore
Imp. L.S.
Covered
S.S.
COAL No. 8
Covered
S.S. (Thick Bed)
COAL No. 7
S.& S.S.
Kidney Ore
Lost Cr.
Slope
Bastard L.S
S.S.
Covered
S.S.
Thin Coal
S.S.S.& S.S.
S.
Rough Ore
S.& S.S.
COAL No. 8
Greenish Shale
Small Kidney Ore
COAL No. 7
Greenish Shale
Kidney Ore
Thin Coal No. 6
L S Ore
L.S.
Dry Fork
Top of Hill
Slope
Calc Rock
Coal Stain
Covered
Coarse S.S.
Covered
Dark Shale
Coal
S & S.S.
Kidney Ore
Coal No. 6
S.
Coarse S.S.
Bed of Cr. below
Falls
Bogart & Folger Cin.
485' Hight above tide at mouth of the Little Sandy River

Plate 14

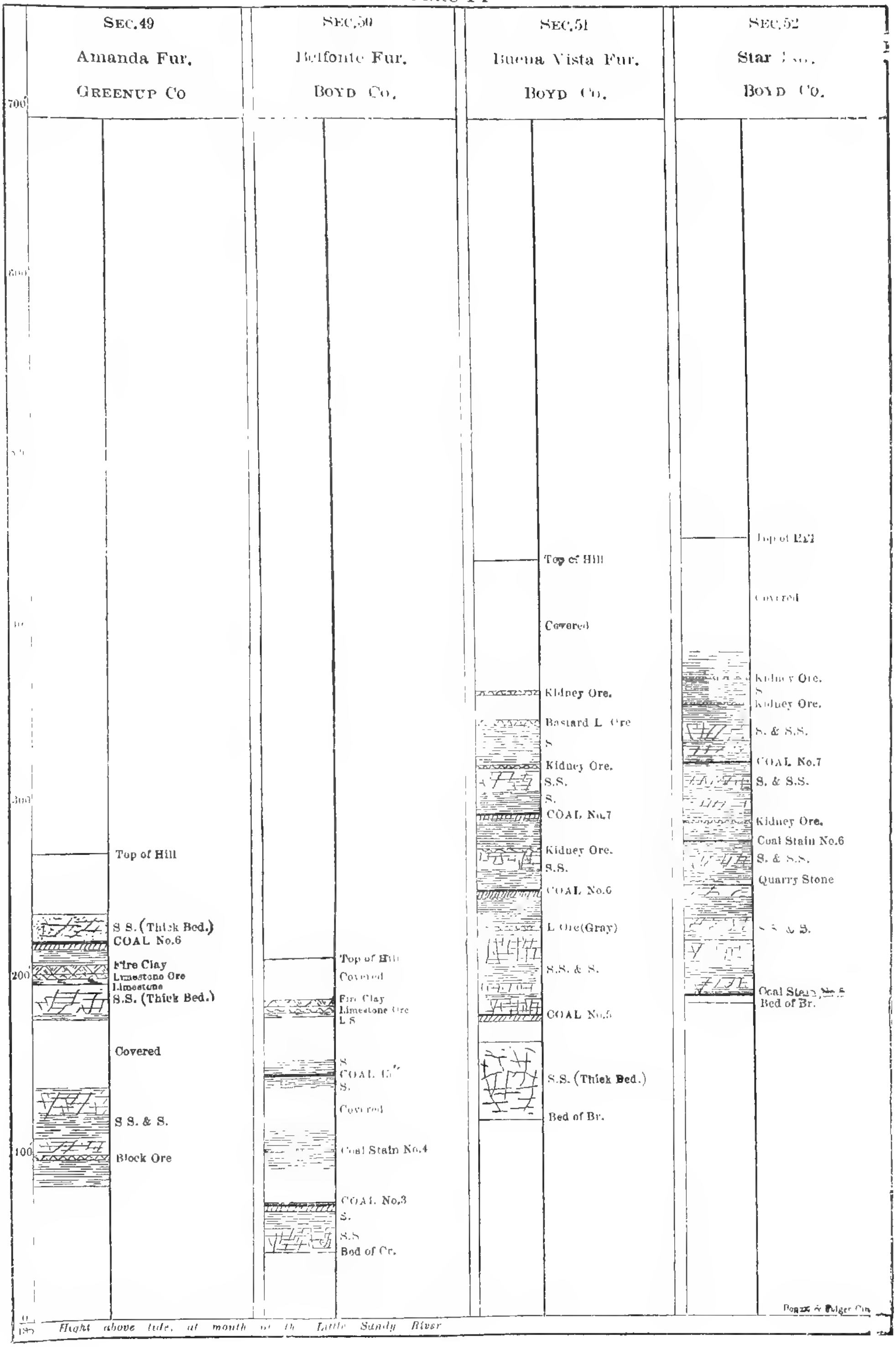

SEC. 49
Amanda Fur.
GREENUP CO
SEC. 50
Belfonte Fur.
BOYD CO.
SEC. 51
Buena Vista Fur.
BOYD CO.
SEC. 52
Star
BOYD CO.
700
300
200
100
Top of Hill
S S. (Thick Bed.)
COAL No.6
Fire Clay
Limestone Ore
Limestone
S.S. (Thick Bed.)
Covered
S S. & S.
Block Ore
Top of Hill
Covered
Fire Clay
Limestone Ore
L S
S.
S.
Covered
Coal Stain No.4
COAL No.3
S.
S.S
Bed of Cr.
Top of Hill
Covered
Kidney Ore.
Bastard L. Ore
S
Kidney Ore.
S.S.
S.
COAL No.7
Kidney Ore.
S.S.
COAL No.6
L Ore (Gray)
S.S. & S.
COAL No.5
S.S. (Thick Bed.)
Bed of Br.
Covered
Kidney Ore.
S
Kidney Ore.
S. & S.S.
COAL No.7
S. & S.S.
Kidney Ore.
Coal Stain No.6
S. & S.S.
Quarry Stone
Bed of Br.
Hight above tide, at mouth of the Little Sandy River
Bogus & Folger Cin

Plate 15

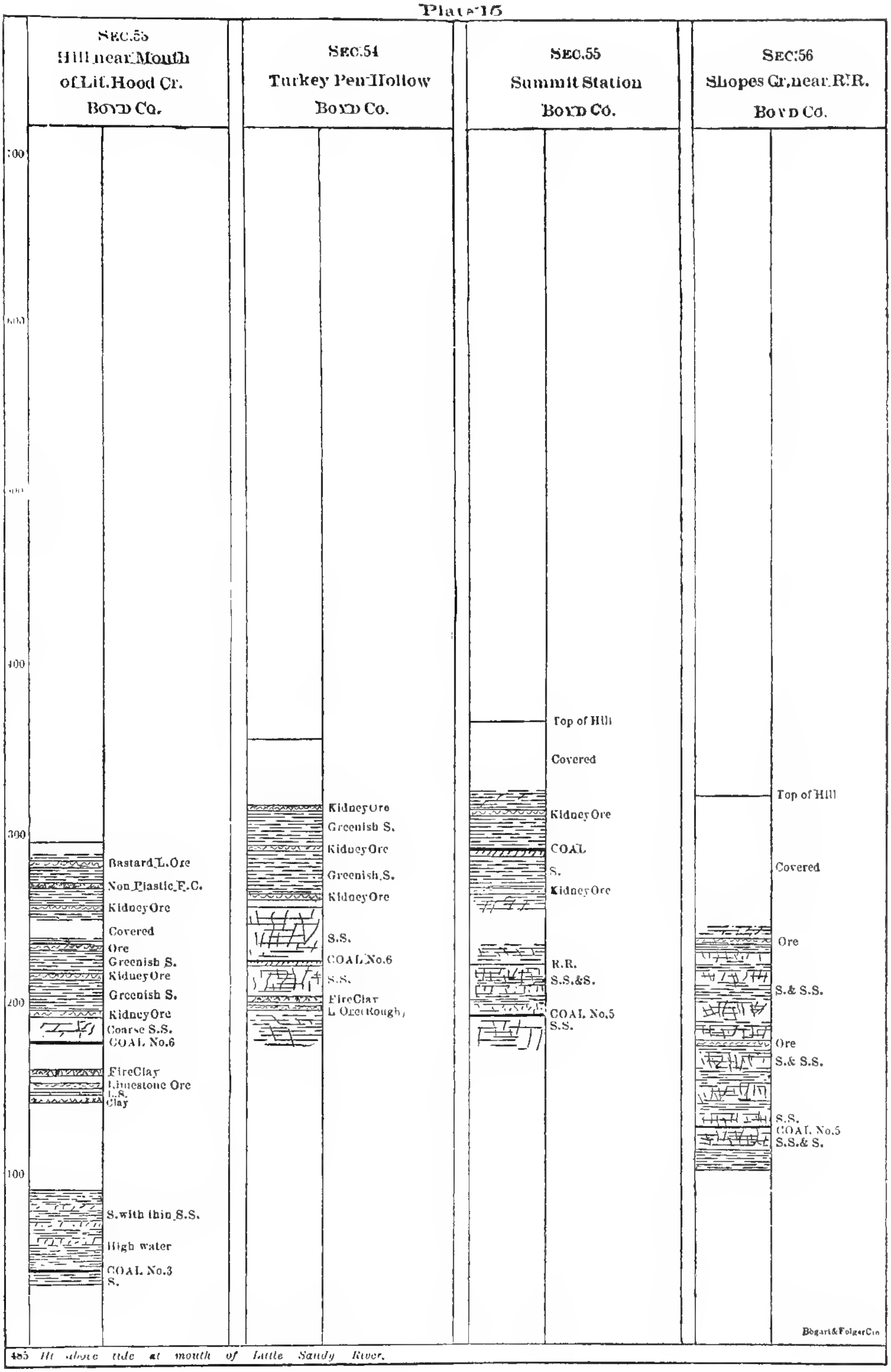

SEC. 53
Hill near Mouth of Lit. Hood Cr.
BOYD CO.
SEC. 54
Turkey Pen Hollow
BOYD CO.
SEC. 55
Summit Station
BOYD CO.
SEC. 56
Shopes Cr. near R.R.
BOYD CO.
700
600
500
400
300
200
100
Bastard L. Ore
Non Plastic F.C.
Kidney Ore
Covered
Ore
Greenish S.
Kidney Ore
Greenish S.
Kidney Ore
Coarse S.S.
COAL No.6
Fire Clay
Limestone Ore
L.S.
Clay
S. with thin S.S.
High water
COAL No.3
S.
Kidney Ore
Greenish S.
Kidney Ore
Greenish S.
Kidney Ore
S.S.
COAL No.6
S.S.
Fire Clay
L. Ore (Rough)
Top of Hill
Covered
Kidney Ore
COAL
S.
Kidney Ore
R.R.
S.S. & S.
COAL No.5
S.S.
Top of Hill
Covered
Ore
S. & S.S.
Ore
S. & S.S.
S.S.
COAL No.5
S.S. & S.
Bogart & Folger Cin.
485 Ft above tide at mouth of Little Sandy River.

Plate 16

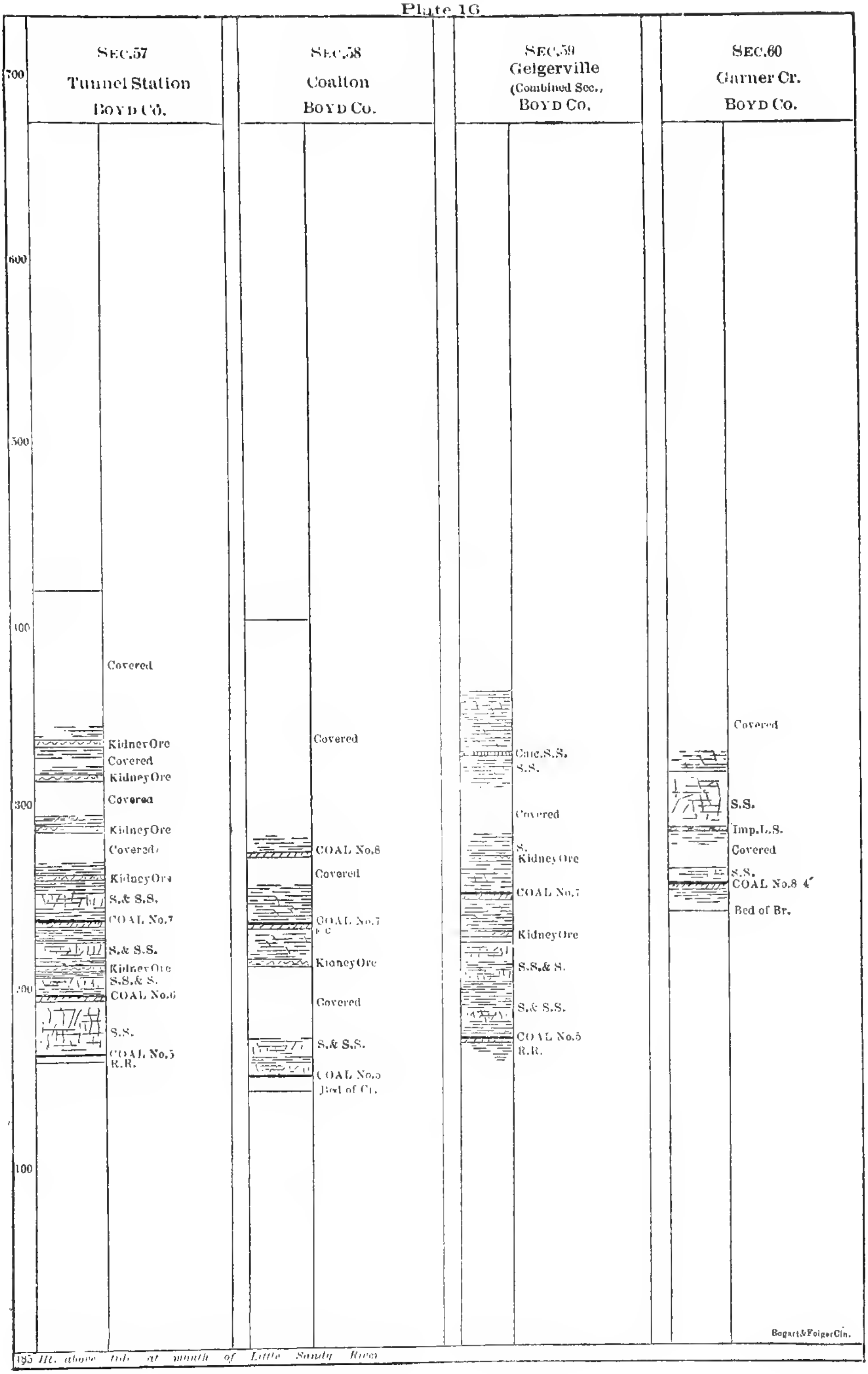
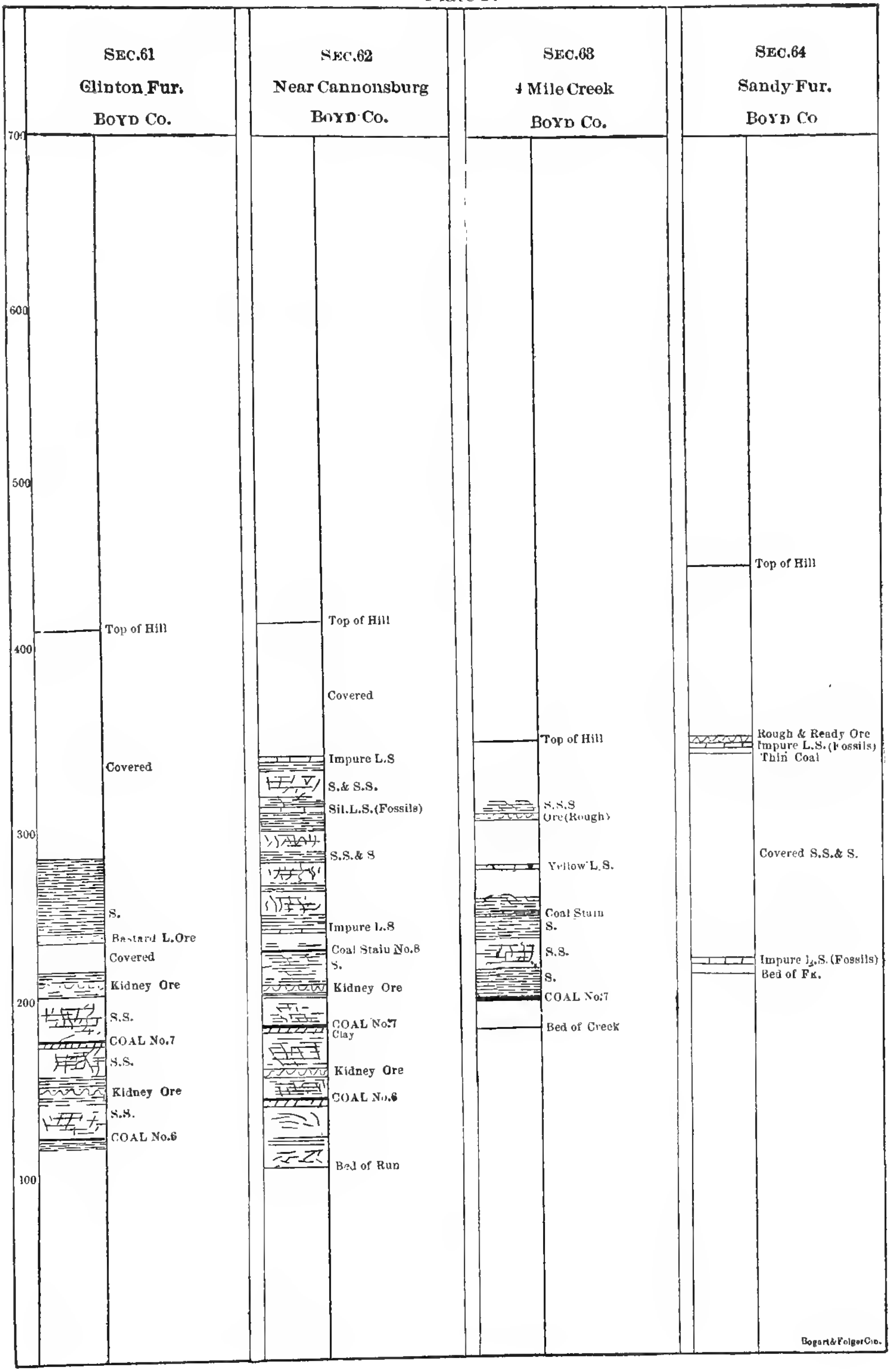
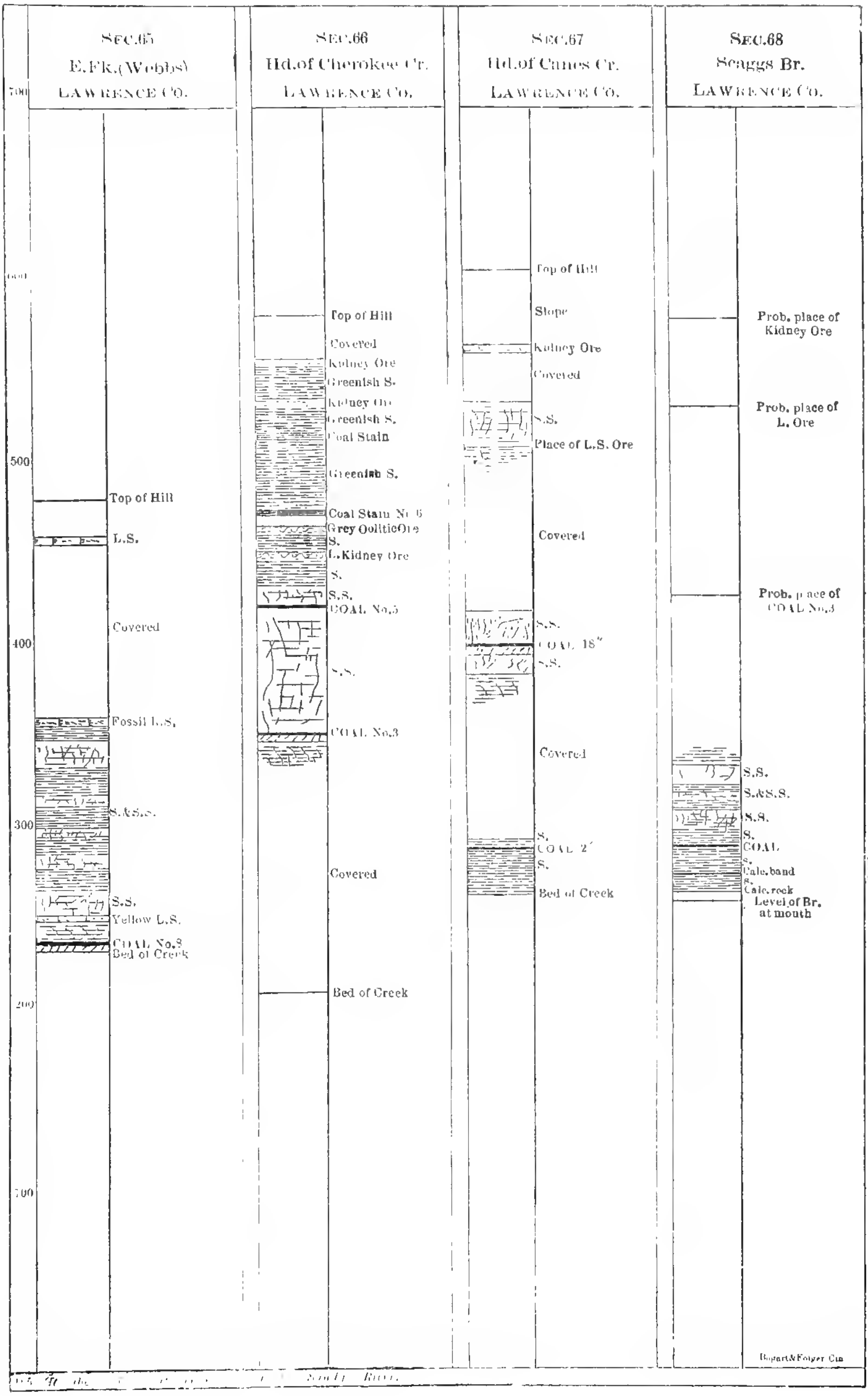

700
600
500
400
300
200
100
SEC.57
Tunnel Station
BOYD CO.
Covered
Kidney Ore
Covered
Kidney Ore
Covered
Kidney Ore
Covered
Kidney Ore
S.& S.S.
COAL No.7
S.& S.S.
Kidney Ore
S.S.& S.
COAL No.6
S.S.
COAL No.5
R.R.
SEC.58
Coalton
BOYD CO.
Covered
COAL No.8
Covered
COAL No.7
Kidney Ore
Covered
S.& S.S.
COAL No.5
Bed of Cr.
SEC.59
Geigerville
(Combined Sec.,
BOYD CO.
Calc.S.S.
S.S.
Covered
S.
Kidney Ore
COAL No.7
Kidney Ore
S.S.& S.
S.& S.S.
COAL No.5
R.R.
SEC.60
Garner Cr.
BOYD CO.
Covered
S.S.
Imp.L.S.
Covered
S.S.
COAL No.8 4"
Bed of Br.
Bogart&FolgerCin.
195 Ft. above tide at mouth of Little Sandy River

Plate 17



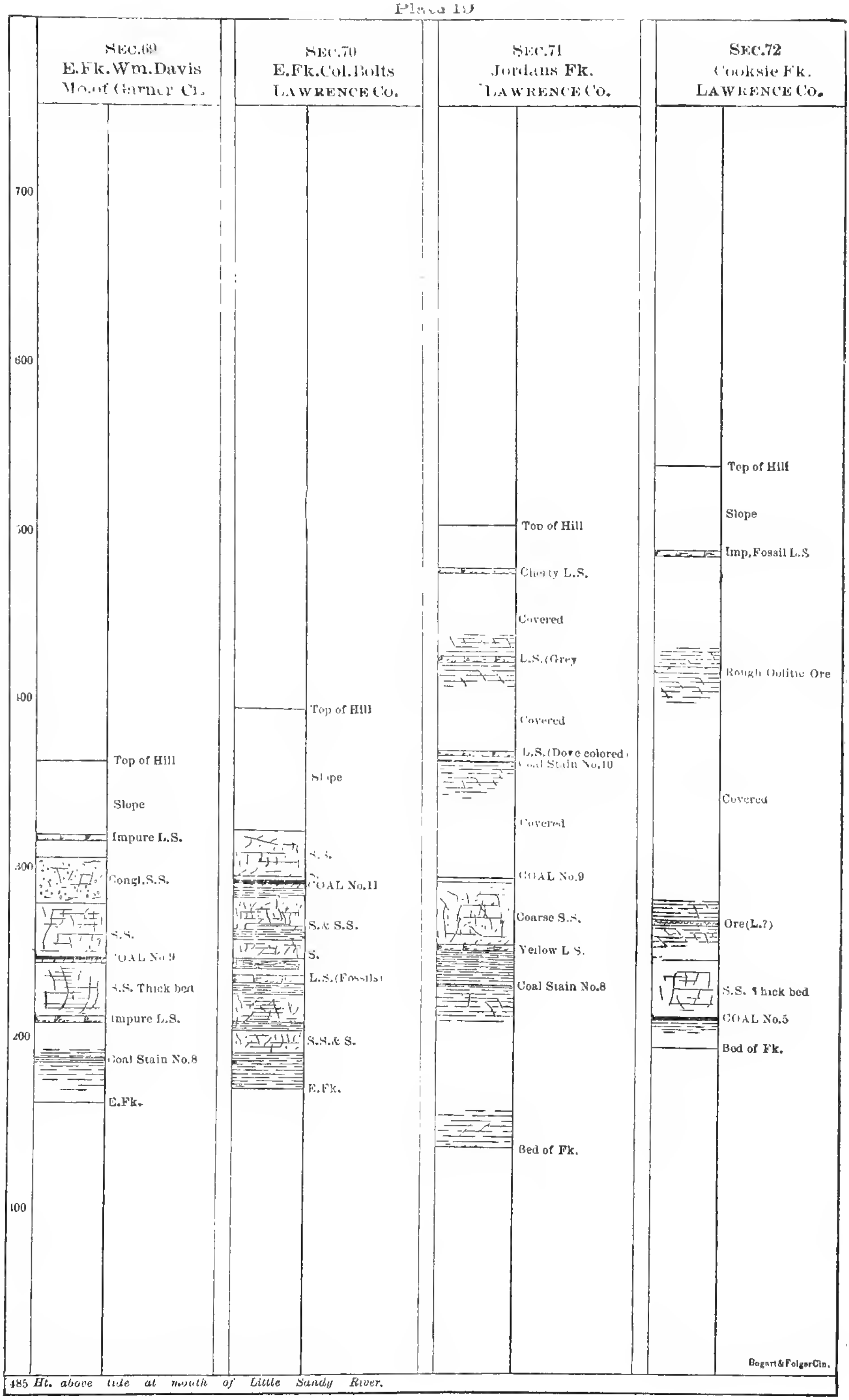
Sec. 61
Clinton Fur.
Boyd Co.
Sec. 62
Near Cannonsburg
Boyd Co.
Sec. 63
4 Mile Creek
Boyd Co.
Sec. 64
Sandy Fur.
Boyd Co
700
600
500
400
300
200
100
Top of Hill
Covered
S.
Bastard L. Ore
Covered
Kidney Ore
S.S.
COAL No. 7
S.S.
Kidney Ore
S.S.
COAL No. 6
Top of Hill
Covered
Impure L.S
S. & S.S.
Sil. L.S. (Fossils)
S.S. & S
Impure L.S
Coal Stain No. 8
S.
Kidney Ore
COAL No. 7
Clay
Kidney Ore
COAL No. 6
Bed of Run
Top of Hill
S.S.S
Ore (Rough)
Yellow L.S.
Coal Stain
S.
S.S.
S.
COAL No. 7
Bed of Creek
Top of Hill
Rough & Ready Ore
Impure L.S. (Fossils)
Thin Coal
Covered S.S. & S.
Impure L.S. (Fossils)
Bed of Fk.
Bogart & Folger Co.

Plate No.18



SEC.65
E.Fk.(Webbs)
LAWRENCE CO.
Top of Hill
L.S.
Covered
Fossil L.S.
S.&S.S.
S.S.
Yellow L.S.
COAL No.3
Bed of Creek
SEC.66
Hd.of Cherokee Cr.
LAWRENCE CO.
Top of Hill
Covered
Kidney Ore
Greenish S.
Kidney Ore
Greenish S.
Coal Stain
Greenish S.
Coal Stain No 6
Grey OolticOre
S.
L.Kidney Ore
S.
S.S.
COAL No.5
S.S.
COAL No.3
Covered
Bed of Creek
SEC.67
Hd.of Canes Cr.
LAWRENCE CO.
Top of Hill
Slope
Kidney Ore
Covered
S.S.
Place of L.S. Ore
Covered
S.S.
COAL 18"
S.S.
Covered
S.
COAL 2'
S.
Bed of Creek
SEC.68
Scaggs Br.
LAWRENCE CO.
Prob. place of Kidney Ore
Prob. place of L. Ore
Prob. place of COAL No.3
S.S.
S.&S.S.
S.S.
S.
COAL
S.
Calc.band
S.
Calc.rock
Level of Br. at mouth
700
600
500
400
300
200
100
Hupart&Folger Cin

Plate 19



Sec. 69
E. Fk. Wm. Davis
Mo. of Garner Cr.
Sec. 70
E. Fk. Col. Bolts
Lawrence Co.
Sec. 71
Jordans Fk.
Lawrence Co.
Sec. 72
Cooksie Fk.
Lawrence Co.
700
600
500
400
300
200
100
Top of Hill
Slope
Impure L.S.
Congl. S.S.
S.S.
COAL No. 9
S.S. Thick bed
Impure L.S.
Coal Stain No. 8
E. Fk.
Top of Hill
Slope
S.S.
COAL No. 11
S. & S.S.
S.
L.S. (Fossils)
S.S. & S.
E. Fk.
Top of Hill
Cherty L.S.
Covered
L.S. (Grey
Covered
L.S. (Dove colored)
Coal Stain No. 10
Covered
COAL No. 9
Coarse S.S.
Yellow L.S.
Coal Stain No. 8
Bed of Fk.
Top of Hill
Slope
Imp. Fossil L.S.
Rough Oolitic Ore
Covered
Ore (L.?)
S.S. Thick bed
COAL No. 5
Bed of Fk.
Bogart & Folger Cin.
485 Ht. above tide at mouth of Little Sandy River.

Plate 20

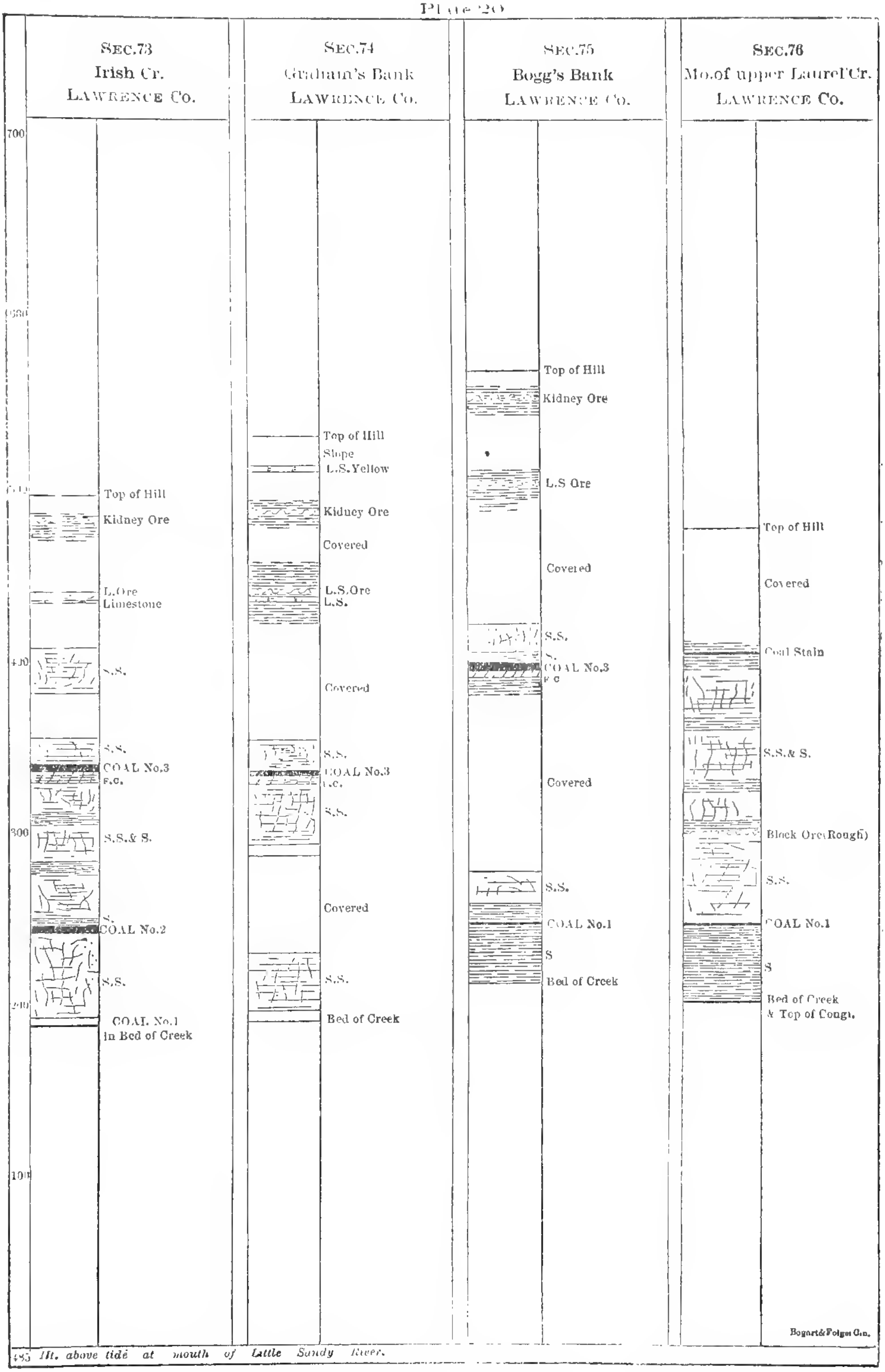
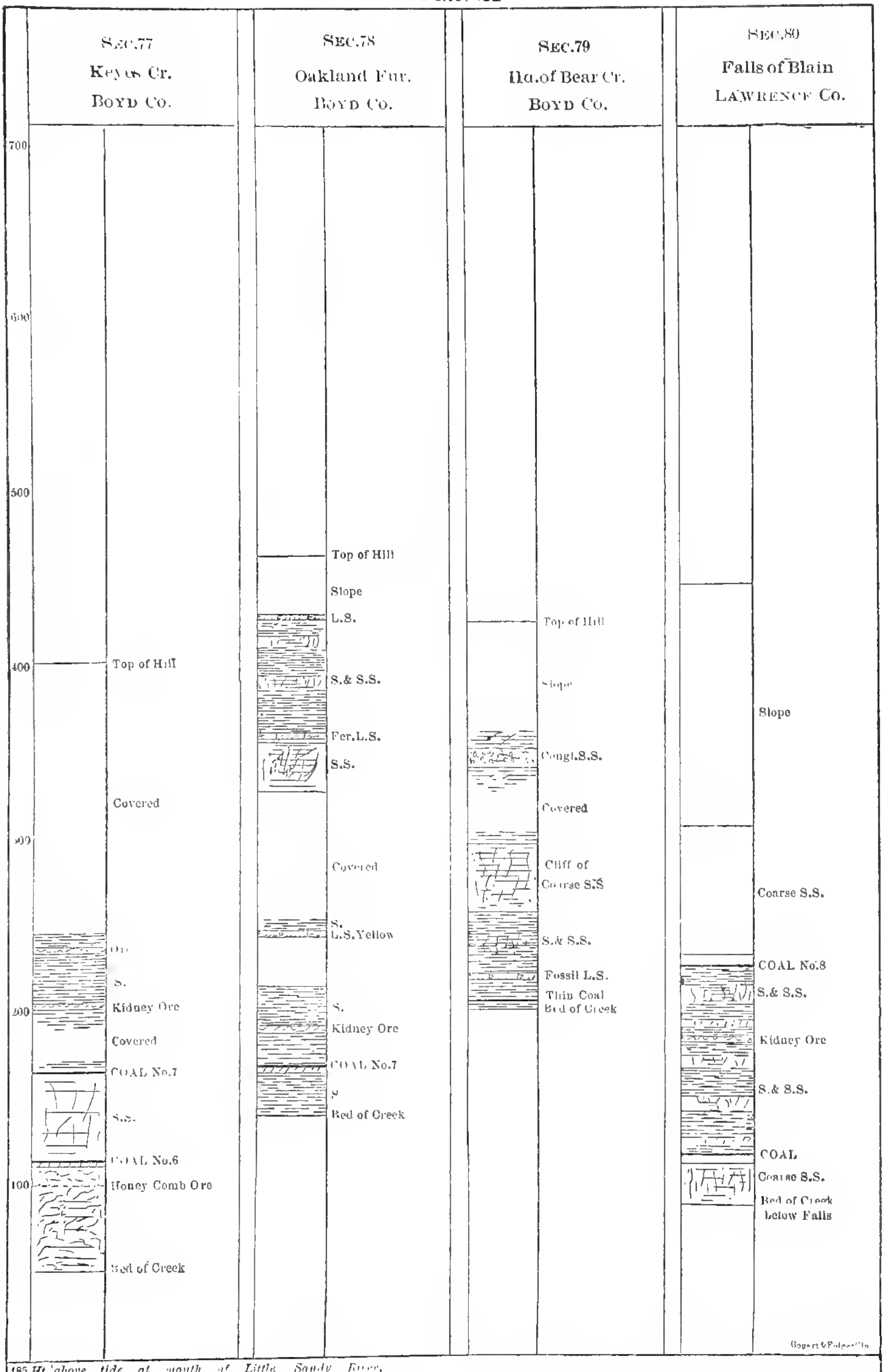

Sec.73
Irish Cr.
Lawrence Co.
Top of Hill
Kidney Ore
L.Ore
Limestone
S.S.
S.S.
COAL No.3
F.C.
S.S.& S.
S.
COAL No.2
S.S.
COAL No.1
in Bed of Creek
Sec.74
Graham's Bank
Lawrence Co.
Top of Hill
Slope
L.S.Yellow
Kidney Ore
Covered
L.S.Ore
L.S.
Covered
S.S.
COAL No.3
F.C.
S.S.
Covered
S.S.
Bed of Creek
Sec.75
Bogg's Bank
Lawrence Co.
Top of Hill
Kidney Ore
L.S Ore
Covered
S.S.
S.
COAL No.3
F.C.
Covered
S.S.
COAL No.1
S
Bed of Creek
Sec.76
Mo.of upper Laurel Cr.
Lawrence Co.
Top of Hill
Covered
Coal Stain
S.S.& S.
Block Ore(Rough)
S.S.
COAL No.1
S
Bed of Creek
& Top of Congl.
700
300
100
485 Ht. above tide at mouth of Little Sandy River.
Bogart&Folger Co.

Plate 21



SEC.77
Keyes Cr.
BOYD CO.
SEC.78
Oakland Fur.
BOYD CO.
SEC.79
Hd.of Bear Cr.
BOYD CO.
SEC.80
Falls of Blain
LAWRENCE CO.
700
600
500
400
300
200
100
Top of Hill
Covered
Ore
S.
Kidney Ore
Covered
COAL No.7
S.S.
COAL No.6
Honey Comb Ore
Bed of Creek
Top of Hill
Slope
L.S.
S.& S.S.
Fer.L.S.
S.S.
Covered
S.
L.S.Yellow
S.
Kidney Ore
COAL No.7
S
Bed of Creek
Top of Hill
Slope
Congl.S.S.
Covered
Cliff of
Coarse S.S
S.& S.S.
Fossil L.S.
Thin Coal
Bed of Creek
Slope
Coarse S.S.
COAL No.8
S.& S.S.
Kidney Ore
S.& S.S.
COAL
Coarse S.S.
Bed of Creek
below Falls
485 Ht. above tide at mouth of Little Sandy River.

Plate No.22

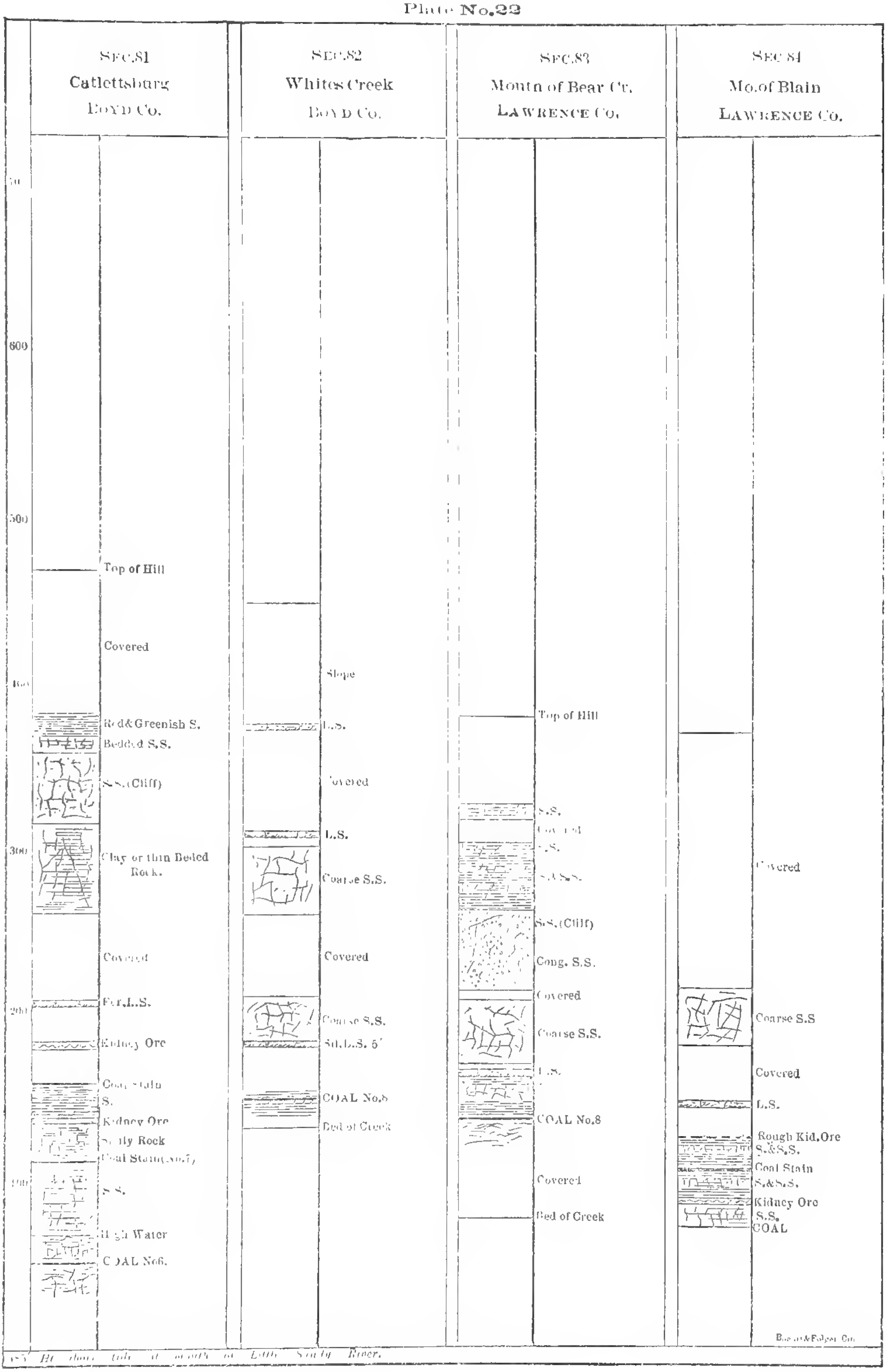
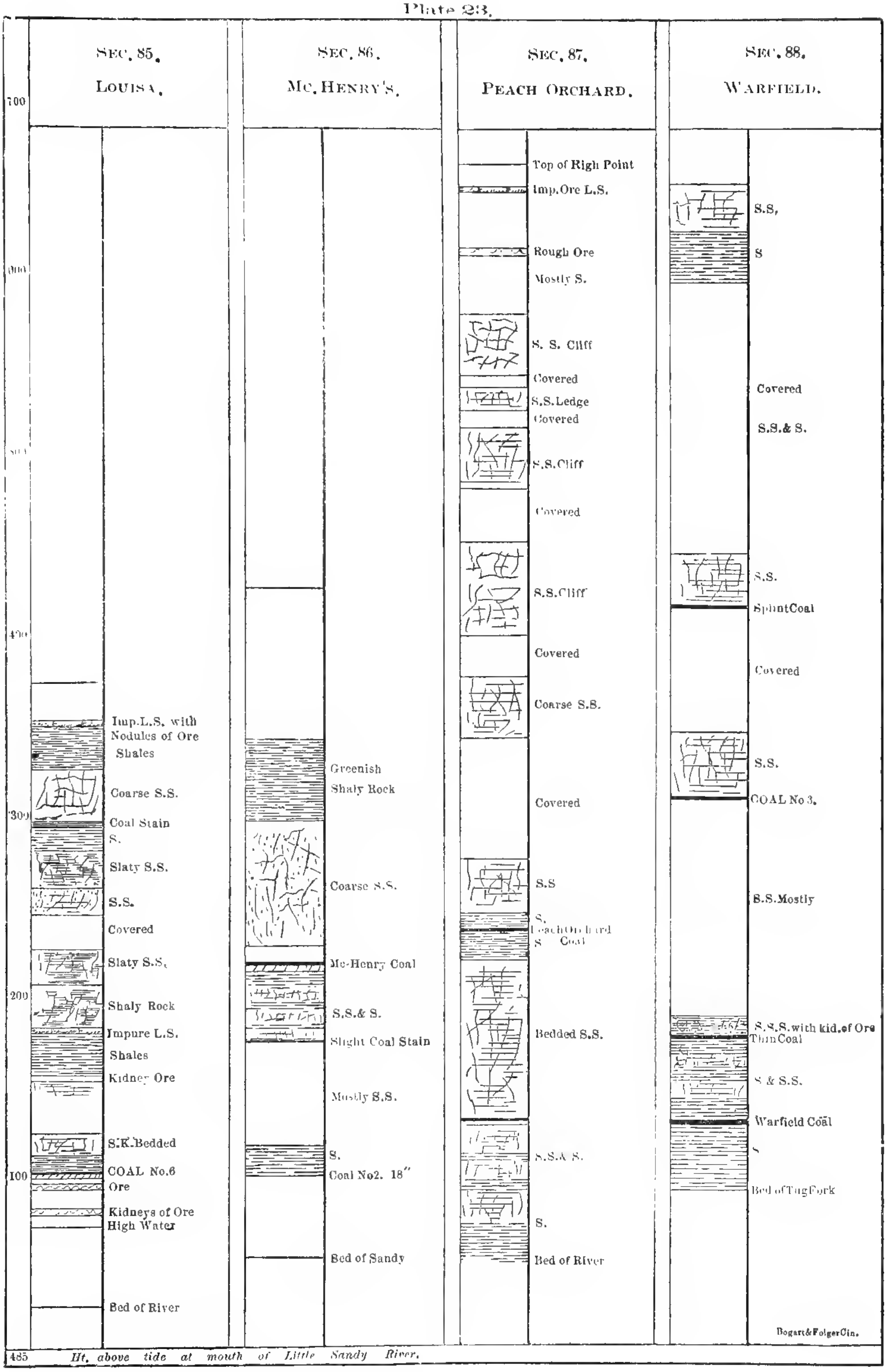
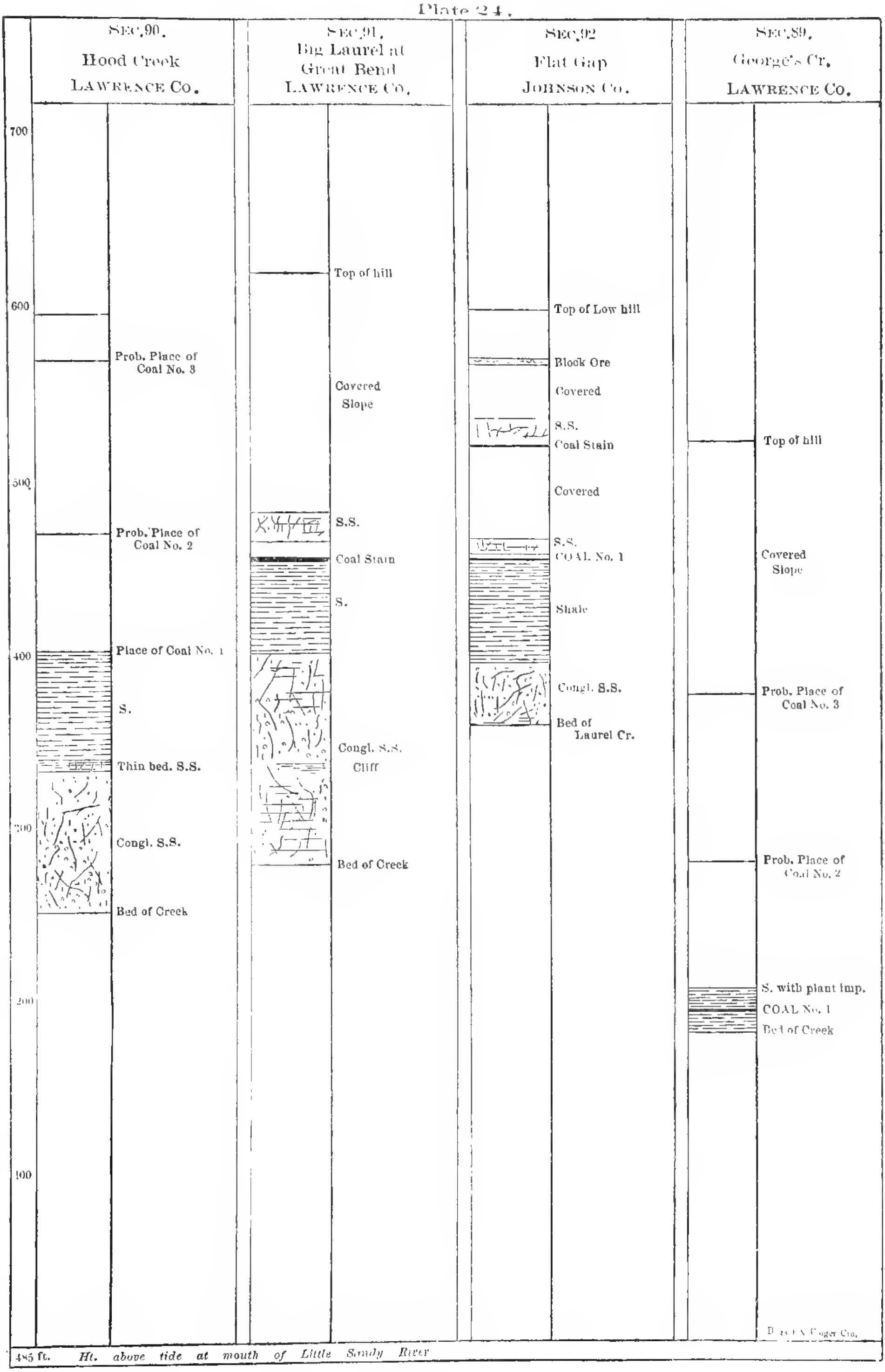

SEC.81
Catlettsburg
BOYD CO.
SEC.82
Whites Creek
BOYD CO.
SEC.83
Mouth of Bear Cr.
LAWRENCE CO.
SEC.84
Mo.of Blain
LAWRENCE CO.
600
500
300
Top of Hill
Covered
Red&Greenish S.
Bedded S.S.
S.S.(Cliff)
Clay or thin Beded Rock.
Covered
Fer.L.S.
Kidney Ore
Coal Stain
S.
Kidney Ore
Rock
Coal Stain(No.7)
S.S.
High Water
COAL No6.
Slope
L.S.
Covered
L.S.
Coarse S.S.
Covered
Coarse S.S.
COAL No.8
Bed of Creek
Top of Hill
S.S.
S.S.(Cliff)
Cong. S.S.
Covered
Coarse S.S.
COAL No.8
Covered
Bed of Creek
Covered
Coarse S.S
Covered
L.S.
Rough Kid.Ore
S.&S.S.
Coal Stain
S.&S.S.
Kidney Ore
S.S.
COAL
River.

Plate 23.



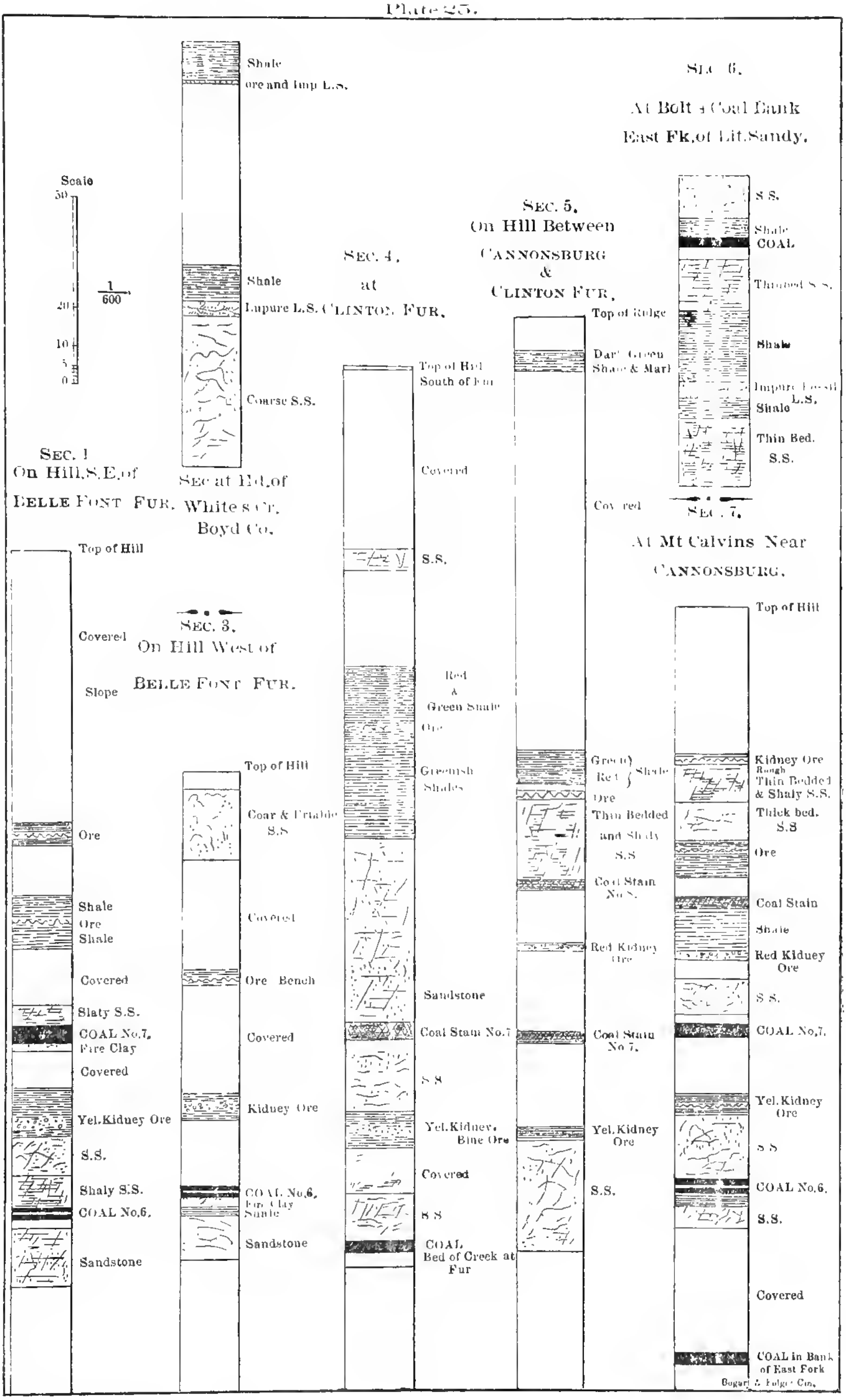
Sec. 85. Louisa.
Sec. 86. Mc. Henry's.
Sec. 87. Peach Orchard.
Sec. 88. Warfield.
700
600
500
400
300
200
100
485 Ht. above tide at mouth of Little Sandy River.
Imp.L.S. with Nodules of Ore
Shales
Coarse S.S.
Coal Stain
S.
Slaty S.S.
S.S.
Covered
Slaty S.S.
Shaly Rock
Impure L.S.
Shales
Kidney Ore
S.K.Bedded
COAL No.6
Ore
Kidneys of Ore
High Water
Bed of River
Greenish Shaly Rock
Coarse S.S.
Mc-Henry Coal
S.S.& S.
Slight Coal Stain
Mostly S.S.
S.
Coal No2. 18"
Bed of Sandy
Top of Righ Point
Imp.Ore L.S.
Rough Ore
Mostly S.
S. S. Cliff
Covered
S.S.Ledge
Covered
S.S.Cliff
Covered
S.S.Cliff
Covered
Coarse S.S.
Covered
S.S
S.
Peach Orchard Coal
S
Bedded S.S.
S.S.& S.
S.
Bed of River
S.S.
S
Covered
S.S.& S.
S.S.
SplintCoal
Covered
S.S.
COAL No 3.
S.S.Mostly
S.S.S.with kid.of Ore
ThinCoal
S & S.S.
Warfield Coal
S
Bed of TugFork
Bogart&FolgerCin.

Plate 24.



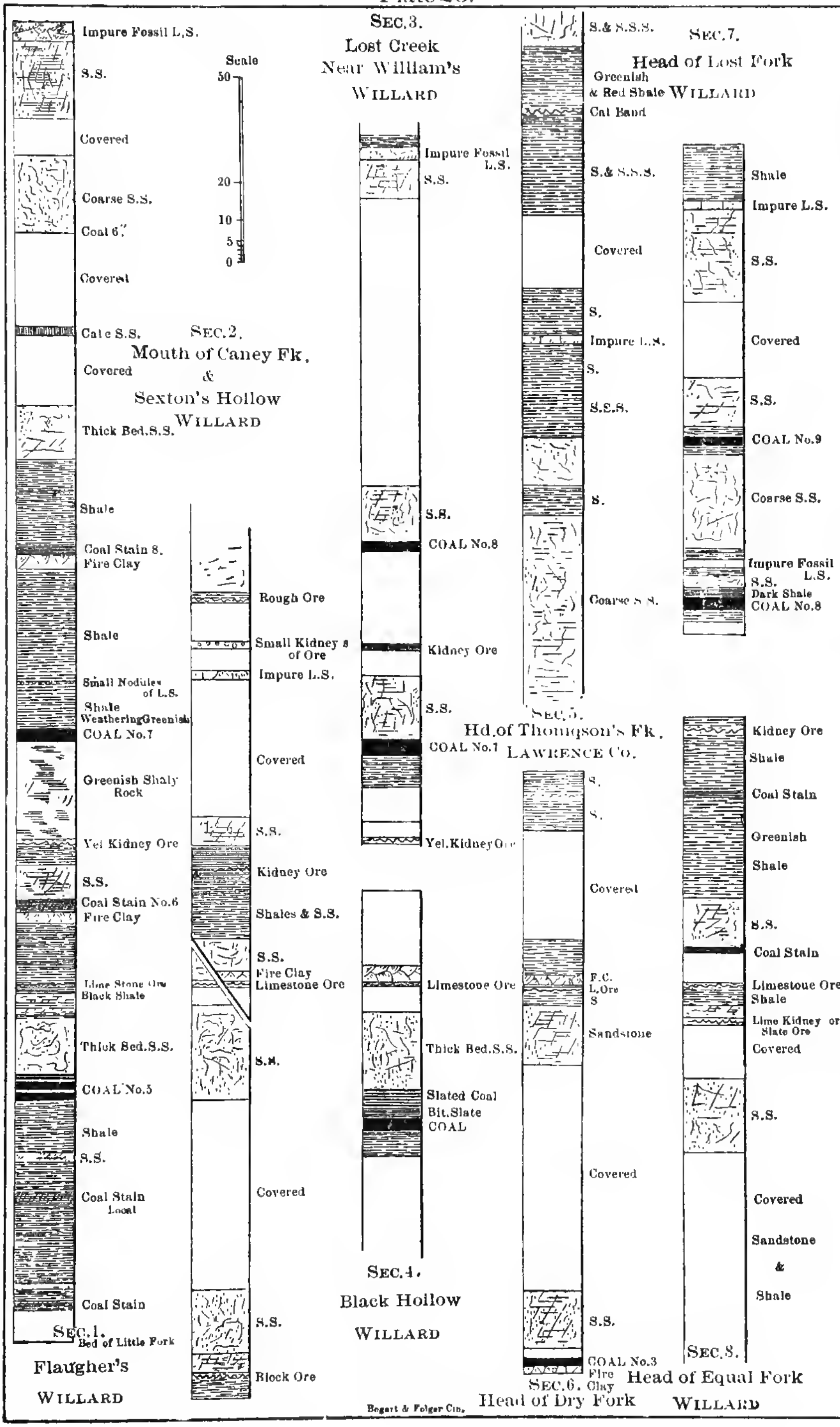
SEC. 90.
Hood Creek
LAWRENCE CO.
SEC. 91.
Big Laurel at
Great Bend
LAWRENCE CO.
SEC. 92
Flat Gap
JOHNSON CO.
SEC. 89.
George's Cr.
LAWRENCE CO.
700
600
500
400
300
200
100
Prob. Place of Coal No. 3
Prob. Place of Coal No. 2
Place of Coal No. 1
S.
Thin bed. S.S.
Congl. S.S.
Bed of Creek
Top of hill
Covered Slope
S.S.
Coal Stain
S.
Congl. S.S. Cliff
Bed of Creek
Top of Low hill
Block Ore
Covered
S.S.
Coal Stain
Covered
S.S.
COAL No. 1
Shale
Congl. S.S.
Bed of Laurel Cr.
Top of hill
Covered Slope
Prob. Place of Coal No. 3
Prob. Place of Coal No. 2
S. with plant imp.
COAL No. 1
Bed of Creek
485 ft. Ht. above tide at mouth of Little Sandy River

Plate 25.



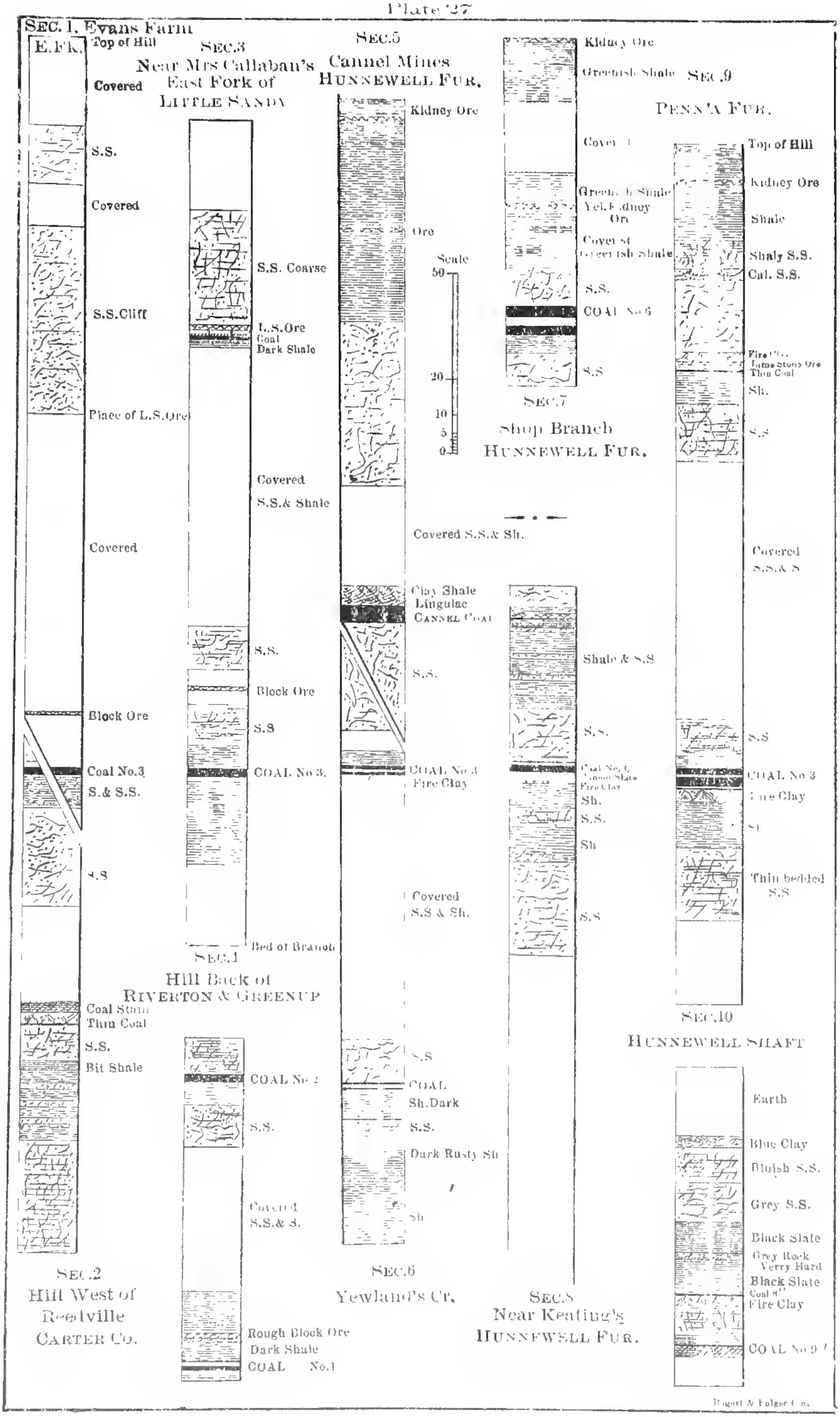
Scale
50
20
10
5
0
1/600
Sec. 1
On Hill S.E. of
Belle Font Fur.
Top of Hill
Covered
Slope
Ore
Shale
Ore
Shale
Covered
Slaty S.S.
COAL No.7.
Fire Clay
Covered
Yel.Kidney Ore
S.S.
Shaly S.S.
COAL No.6.
Sandstone
Sec at Hd. of
White's Cr.
Boyd Co.
Shale
ore and Imp L.S.
Shale
Impure L.S.
Coarse S.S.
Sec. 3.
On Hill West of
Belle Font Fur.
Top of Hill
Coar & Friable S.S
Covered
Ore Bench
Covered
Kidney Ore
COAL No.6.
Fire Clay
Shale
Sandstone
Sec. 4.
at
Clinton Fur.
Top of Hill
South of Fur
Covered
S.S.
Red
&
Green Shale
Ore
Greenish
Shales
Sandstone
Coal Stain No.7
S.S
Yel.Kidney.
Blue Ore
Covered
S.S
COAL
Bed of Creek at
Fur
Sec. 5.
On Hill Between
Cannonsburg
&
Clinton Fur.
Top of Ridge
Dark Green
Shale & Marl
Covered
Green
Red
Shale
Ore
Thin Bedded
and Shaly
S.S
Coal Stain
No.8.
Red Kidney
Ore
Coal Stain
No 7.
Yel. Kidney
Ore
S.S.
Sec. 6.
At Bolt's Coal Bank
East Fk. of Lit. Sandy.
S.S.
Shale
COAL
Thinbed S.S.
Shale
Impure Fossil
L.S.
Shale
Thin Bed.
S.S.
Sec. 7.
At Mt Calvins Near
Cannonsburg.
Top of Hill
Kidney Ore
Rough
Thin Bedded
& Shaly S.S.
Thick bed.
S.S
Ore
Coal Stain
Shale
Red Kidney
Ore
S.S.
COAL No.7.
Yel. Kidney
Ore
S.S
COAL No.6.
S.S.
Covered
COAL in Bank
of East Fork
Bogart & Folger Co.

Plate 26.



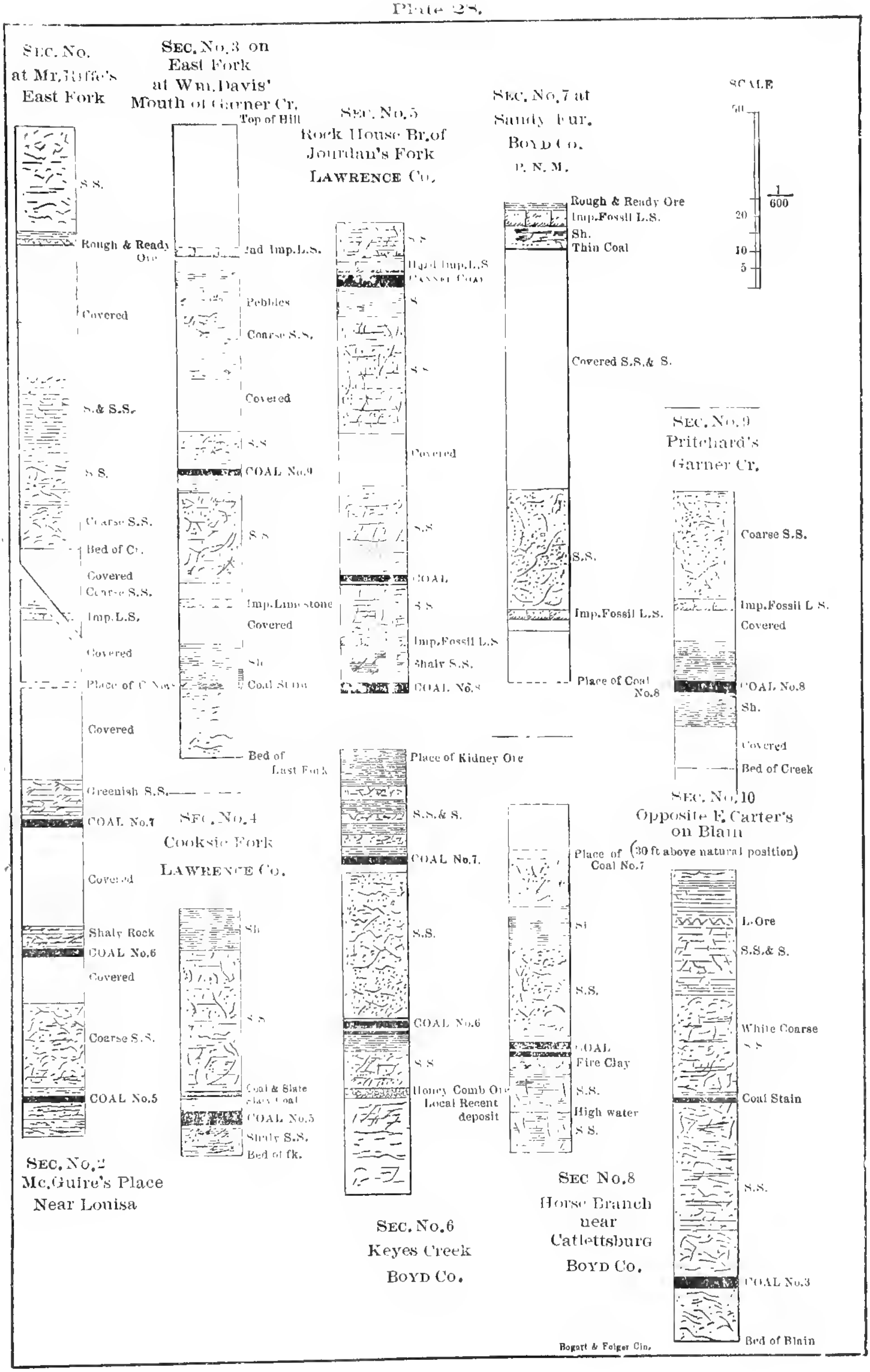
Impure Fossil L.S.
S.S.
Covered
Coarse S.S.
Coal 6"
Covered
Calc S.S.
Covered
Thick Bed.S.S.
Shale
Coal Stain 8.
Fire Clay
Shale
Small Nodules of L.S.
Shale Weathering Greenish
COAL No.7
Greenish Shaly Rock
Yel Kidney Ore
S.S.
Coal Stain No.6
Fire Clay
Lime Stone Ore
Black Shale
Thick Bed.S.S.
COAL No.5
Shale
S.S.
Coal Stain Local
Coal Stain
SEC.1.
Bed of Little Fork
Flaugher's
WILLARD
Scale
50
20
10
5
0
SEC.2.
Mouth of Caney Fk.
&
Sexton's Hollow
WILLARD
Rough Ore
Small Kidney s of Ore
Impure L.S.
Covered
S.S.
Kidney Ore
Shales & S.S.
S.S.
Fire Clay
Limestone Ore
S.S.
Covered
S.S.
Block Ore
SEC.3.
Lost Creek
Near William's
WILLARD
Impure Fossil L.S.
S.S.
S.S.
COAL No.8
Kidney Ore
S.S.
COAL No.7
Yel.Kidney Ore
Limestone Ore
Thick Bed.S.S.
Slated Coal
Bit.Slate
COAL
SEC.4.
Black Hollow
WILLARD
S.& S.S.S.
Greenish & Red Shale
Cal Band
S.& S.S.S.
Covered
S.
Impure L.S.
S.
S.S.S.
S.
Coarse S.S.
SEC.5.
Hd.of Thompson's Fk.
LAWRENCE CO.
S.
S.
Covered
F.C.
L.Ore
S
Sandstone
Covered
S.S.
COAL No.3
Fire Clay
SEC.6.
Head of Dry Fork
SEC.7.
Head of Lost Fork
WILLARD
Shale
Impure L.S.
S.S.
Covered
S.S.
COAL No.9
Coarse S.S.
Impure Fossil L.S.
S.S.
Dark Shale
COAL No.8
Kidney Ore
Shale
Coal Stain
Greenish Shale
S.S.
Coal Stain
Limestone Ore
Shale
Lime Kidney or Slate Ore
Covered
S.S.
Covered
Sandstone & Shale
SEC.8.
Head of Equal Fork
WILLARD
Bogart & Folger Cin.

Plate 27



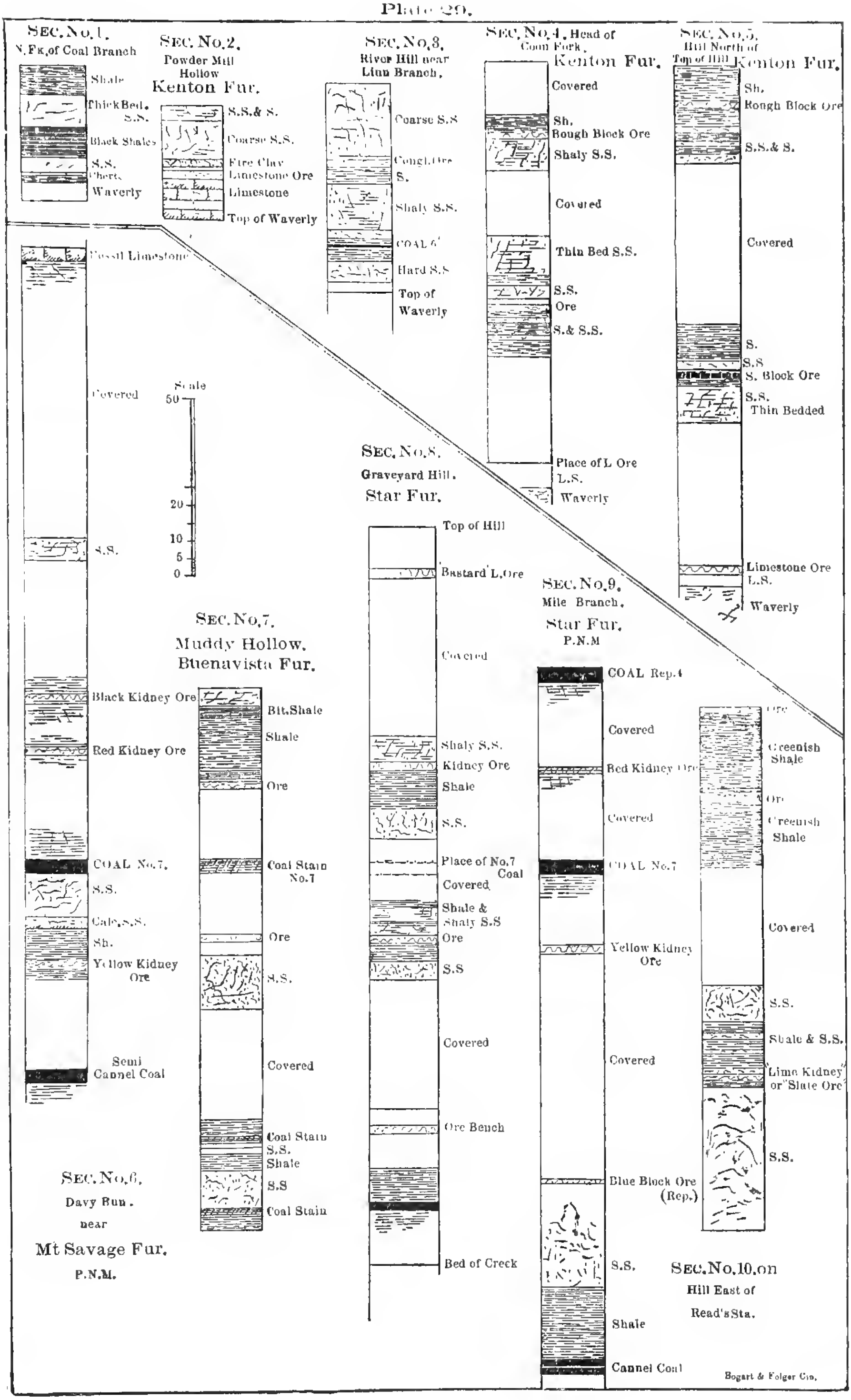
SEC. 1, Evans Farm
E.F.K.
Top of Hill
Covered
S.S.
Covered
S.S.Cliff
Place of L.S.Ore
Covered
Block Ore
Coal No.3
S.& S.S.
S.S
Coal Stain
Thin Coal
S.S.
Bit Shale
SEC.2
Hill West of
Reedville
CARTER CO.
SEC.3
Near Mrs Callahan's
East Fork of
LITTLE SANDY
S.S. Coarse
L.S.Ore
Coal
Dark Shale
Covered
S.S.& Shale
S.S.
Block Ore
S.S
COAL No.3.
Bed of Branch
SEC.4
Hill Back of
RIVERTON & GREENUP
COAL No.2
S.S.
Covered
S.S.& S.
Rough Block Ore
Dark Shale
COAL No.1
SEC.5
Cannel Mines
HUNNEWELL FUR.
Kidney Ore
Ore
Scale
50
20
10
5
0
Covered S.S.& Sh.
Clay Shale
Lingulae
CANNEL COAL
S.S.
COAL No.3
Fire Clay
Covered
S.S & Sh.
S.S
COAL
Sh.Dark
S.S.
Dark Rusty Sh
Sh
SEC.6
Yewland's Cr.
Kidney Ore
Greenish Shale
Covered
Greenish Shale
Yel.Kidney Ore
Covered
Greenish Shale
S.S.
COAL No.6
S.S
SEC.7
Shop Branch
HUNNEWELL FUR.
Shale & S.S
S.S.
Coal No.6
Cannel Slate
Fire Clay
Sh.
S.S.
Sh
S.S
SEC.8
Near Keating's
HUNNEWELL FUR.
SEC.9
PENN'A FUR.
Top of Hill
Kidney Ore
Shale
Shaly S.S.
Cal. S.S.
Fire Clay
Lime Stone Ore
Thin Coal
Sh.
S.S
Covered
S.S.& S.
S.S
COAL No.3
Fire Clay
S.S
Thin bedded
S.S
SEC.10
HUNNEWELL SHAFT
Earth
Blue Clay
Bluish S.S.
Grey S.S.
Black Slate
Grey Rock
Verry Hard
Black Slate
Coal 8"
Fire Clay
COAL No.2
Hagert & Folger Co.

Plate 28.



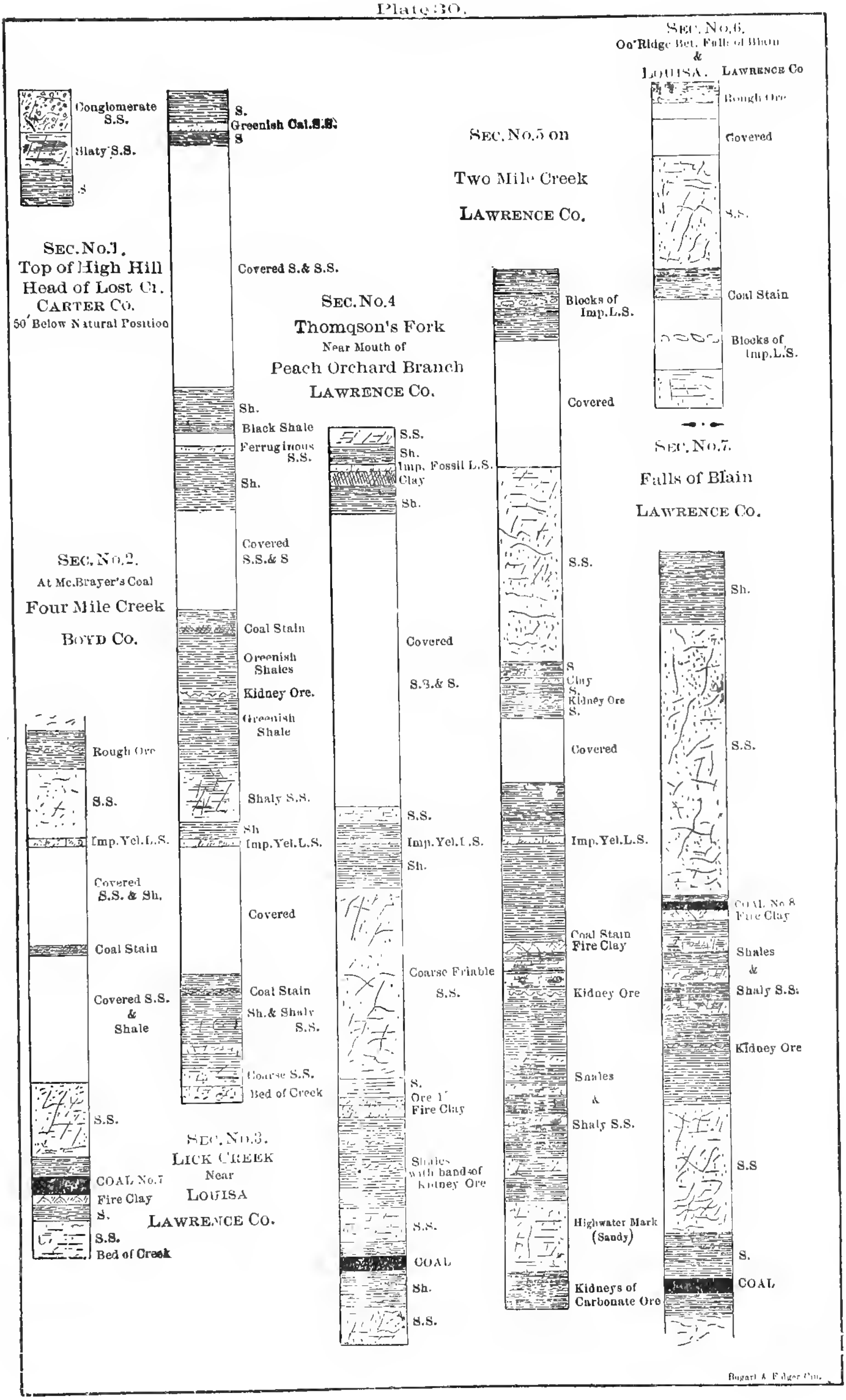
Sec. No.
at Mr. Roffe's
East Fork
S.S.
Rough & Ready Ore
Covered
S.& S.S.
S.S.
Coarse S.S.
Bed of Cr.
Covered
Coarse S.S.
Imp. L.S.
Covered
Place of C. No.8
Covered
Greenish S.S.
COAL No.7
Covered
Shaly Rock
COAL No.6
Covered
Coarse S.S.
COAL No.5
Sec. No. 2
Mc.Guire's Place
Near Louisa
Sec. No. 3 on
East Fork
at Wm. Davis'
Mouth of Garner Cr.
Top of Hill
2nd Imp. L.S.
Pebbles
Coarse S.S.
Covered
S.S
COAL No.9
S.S
Imp. Limestone
Covered
Sh
Coal Stain
Bed of
Last Fork
Sec. No. 4
Cooksie Fork
Lawrence Co.
Sh
S.S
Coal & Slate
Slaty Coal
COAL No.5
Shaly S.S.
Bed of fk.
Sec. No. 5
Rock House Br. of
Jourdan's Fork
Lawrence Co.
S.S
Hard Imp. L.S
Cannel Coal
S
S.S
Covered
S.S
COAL
S.S
Imp. Fossil L.S
Shaly S.S.
COAL No.8
Place of Kidney Ore
S.S.& S.
COAL No.7.
S.S.
COAL No.6
S.S
Honey Comb Ore
Local Recent deposit
Sec. No. 6
Keyes Creek
Boyd Co.
Sec. No. 7 at
Sandy Fur.
Boyd Co.
P. N. M.
Rough & Ready Ore
Imp. Fossil L.S.
Sh.
Thin Coal
Covered S.S.& S.
S.S.
Imp. Fossil L.S.
Place of Coal No.8
Place of (30 ft above natural position)
Coal No.7
Sh
S.S.
COAL
Fire Clay
S.S.
High water
S.S.
Sec No. 8
Horse Branch
near
Catlettsburg
Boyd Co.
Sec. No. 9
Pritchard's
Garner Cr.
Coarse S.S.
Imp. Fossil L.S.
Covered
COAL No.8
Sh.
Covered
Bed of Creek
Sec. No. 10
Opposite E. Carter's
on Blain
L. Ore
S.S.& S.
White Coarse S.S.
Coal Stain
S.S.
COAL No.3
Bed of Blain
SCALE
50
20
10
5
1/600
Bogart & Folger Cin.

Plate 29.

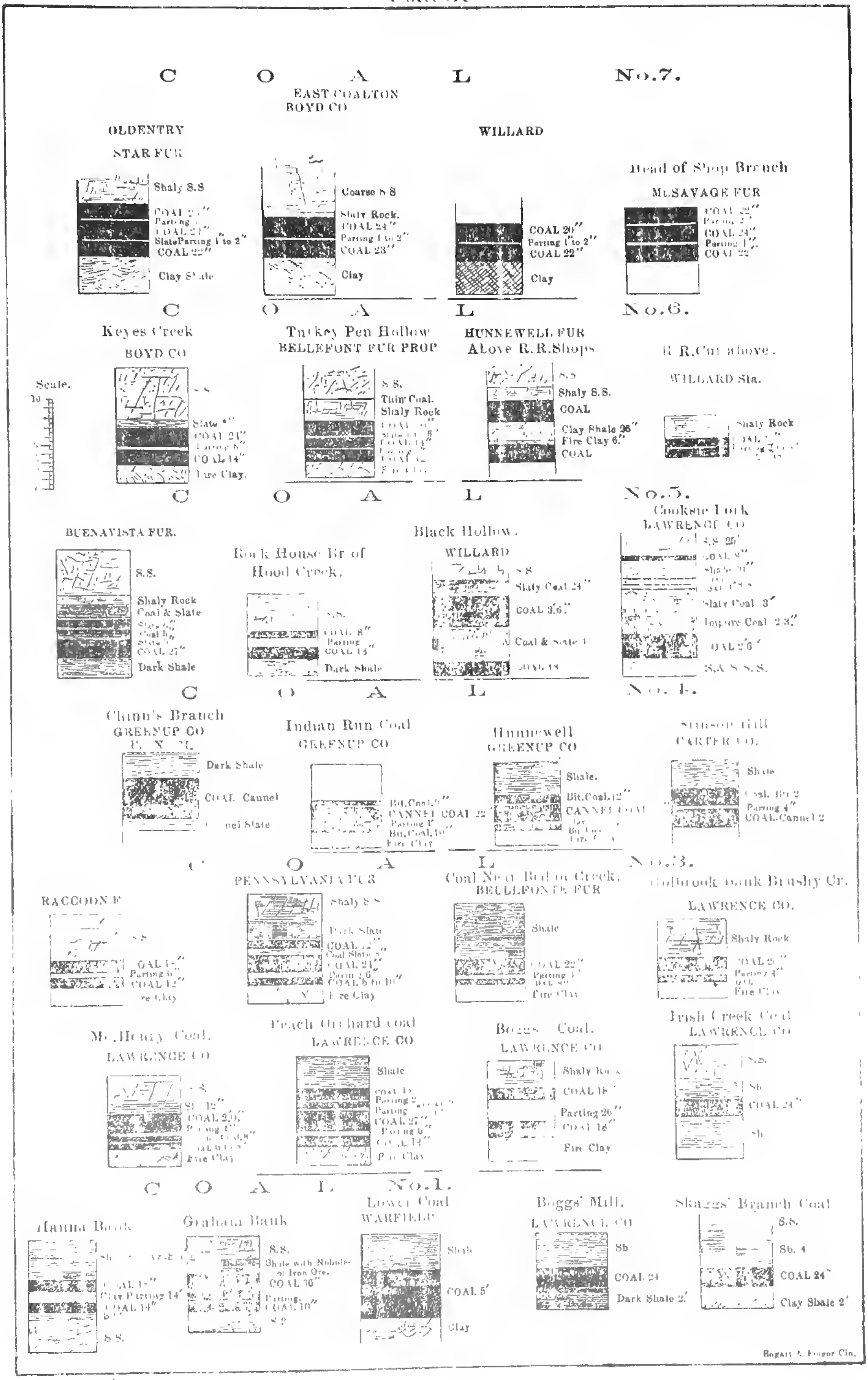


Sec. No. 1. N. Fk. of Coal Branch
Shale
Thick Bed. S.S.
Black Shales
S.S.
Chert.
Waverly
Sec. No. 2. Powder Mill Hollow Kenton Fur.
S.S. & S.
Coarse S.S.
Fire Clay
Limestone Ore
Limestone
Top of Waverly
Sec. No. 3. River Hill near Linn Branch.
Coarse S.S.
Congl. Ore
S.
Shaly S.S.
COAL 6'
Hard S.S.
Top of Waverly
Sec. No. 4. Head of Coon Fork, Kenton Fur.
Covered
Sh.
Rough Block Ore
Shaly S.S.
Covered
Thin Bed S.S.
S.S.
Ore
S. & S.S.
Place of L Ore
L.S.
Waverly
Sec. No. 5. Hill North of Kenton Fur.
Top of Hill
Sh.
Rough Block Ore
S.S. & S.
Covered
S.
S.S
S. Block Ore
S.S. Thin Bedded
Limestone Ore
L.S.
Waverly
Fossil Limestone
Covered
Scale
50
20
10
5
0
S.S.
Black Kidney Ore
Red Kidney Ore
COAL No. 7.
S.S.
Calc. S.S.
Sh.
Yellow Kidney Ore
Semi Cannel Coal
Sec. No. 6. Davy Run. near Mt Savage Fur. P.N.M.
Sec. No. 7. Muddy Hollow. Buenavista Fur.
Bit. Shale
Shale
Ore
Coal Stain No. 7
Ore
S.S.
Covered
Coal Stain
S.S.
Shale
S.S
Coal Stain
Sec. No. 8. Graveyard Hill. Star Fur.
Top of Hill
Bastard L. Ore
Covered
Shaly S.S.
Kidney Ore
Shale
S.S.
Place of No. 7 Coal
Covered
Shale & Shaly S.S
Ore
S.S
Covered
Ore Bench
Bed of Creek
Sec. No. 9. Mile Branch. Star Fur. P.N.M
COAL Rep. 4
Covered
Red Kidney Ore
Covered
COAL No. 7
Yellow Kidney Ore
Covered
Blue Block Ore (Rep.)
S.S.
Shale
Cannel Coal
Ore
Greenish Shale
Ore
Greenish Shale
Covered
S.S.
Shale & S.S.
"Lime Kidney" or "Slate Ore"
S.S.
Sec. No. 10. on Hill East of Read's Sta.
Bogart & Folger Co.

Plate 30.



Sec. No.1.
Top of High Hill
Head of Lost Cr.
Carter Co.
50' Below Natural Position
Conglomerate S.S.
Slaty S.S.
S
Sec. No.2.
At Mc.Brayer's Coal
Four Mile Creek
Boyd Co.
Rough Ore
S.S.
Imp. Yel. L.S.
Covered S.S. & Sh.
Coal Stain
Covered S.S. & Shale
S.S.
COAL No.7
Fire Clay
S.
S.S.
Bed of Creek
Sec. No.3.
Lick Creek
Near
Louisa
Lawrence Co.
S.
Greenish Cal. S.S.
S
Covered S.& S.S.
Sh.
Black Shale
Ferruginous S.S.
Sh.
Covered S.S.& S
Coal Stain
Greenish Shales
Kidney Ore.
Greenish Shale
Shaly S.S.
Sh
Imp. Yel. L.S.
Covered
Coal Stain
Sh.& Shaly S.S.
Coarse S.S.
Bed of Creek
Sec. No.4
Thomqson's Fork
Near Mouth of
Peach Orchard Branch
Lawrence Co.
S.S.
Sh.
Imp. Fossil L.S.
Clay
Sh.
Covered
S.S.& S.
S.S.
Imp. Yel. L.S.
Sh.
Coarse Friable S.S.
S.
Ore 1"
Fire Clay
Shales with bands of Kidney Ore
S.S.
COAL
Sh.
S.S.
Sec. No.5 on
Two Mile Creek
Lawrence Co.
Blocks of Imp. L.S.
Covered
S.S.
S
Clay
S.
Kidney Ore
S.
Covered
Imp. Yel. L.S.
Coal Stain
Fire Clay
Kidney Ore
Shales & Shaly S.S.
Highwater Mark (Sandy)
Kidneys of Carbonate Ore
Sec. No.6.
On Ridge Bet. Falls of Blain & Louisa.
Lawrence Co
Rough Ore
Covered
S.S.
Coal Stain
Blocks of Imp. L.S.
Sec. No.7.
Falls of Blain
Lawrence Co.
Sh.
S.S.
COAL No 8
Fire Clay
Shales & Shaly S.S.
Kidney Ore
S.S
S.
COAL
Bogart & Folger Cin.


C O A L No.7.
EAST COALTON
BOYD CO
OLDENTRY
STAR FUR
Shaly S.S
WILLARD
Head of Shop Branch
Mt.SAVAGE FUR
Coarse S S
Shaly Rock.
COAL 24"
COAL 23"
Clay
COAL 20"
Parting 1" to 2"
COAL 22"
Clay
COAL 22"
C O A L No.6.
Keyes Creek
BOYD CO
Turkey Pen Hollow
BELLEFONT FUR PROP
HUNNEWELL FUR
Above R.R.Shops
R.R.Cut above.
WILLARD Sta.
Scale.
10
S S.
Thin Coal.
Shaly Rock
Shaly S.S.
COAL
Clay Shale 26"
Fire Clay 6"
COAL
Shaly Rock
COAL 24"
COAL 14"
Fire Clay.
C O A L No.5.
Cooksie Fork
LAWRENCE CO
BUENAVISTA FUR.
Rock House Br of
Hood Creek.
Black Hollow.
WILLARD
S.S.
Shaly Rock
Coal & Slate
COAL 27"
Dark Shale
COAL 8"
Parting
COAL 13"
Dark Shale
Slaty Coal 24"
COAL 3,6"
Coal & Slate
Slaty Coal 3"
Impure Coal 2'3"
C O A L No.4.
Chinn's Branch
GREENUP CO
Indian Run Coal
GREENUP CO
Hunnewell
GREENUP CO
CARTER CO.
Dark Shale
COAL Cannel
Bit.Coal
CANNEL COAL 22
Parting 1"
Fire Clay
Shale.
Bit.Coal 12"
Shale
Parting 4"
COAL-Cannel 2
C O A L No.3.
RACCOON F
PENNSYLVANIA FUR
Coal Near Bed in Creek.
BELLEFONTE FUR
LAWRENCE CO.
Shaly S S
COAL 21"
Fire Clay
Shale
COAL 22"
Fire Clay
Shaly Rock
Fire Clay
Peach Orchard coal
LAWRENCE CO
Irish Creek Coal
LAWRENCE CO
LAWRENCE CO
Boggs Coal.
LAWRENCE CO
Shale
Fire Clay
Shaly Rock
COAL 18"
Parting 26"
COAL 16"
Fire Clay
COAL 24"
C O A L No.1.
Lower Coal
WARFIELD
Boggs' Mill.
LAWRENCE CO
Skaggs' Branch Coal
Graham Bank
S.S.
Shale with Nodules of Iron Ore.
COAL 30"
Parting.
COAL 30"
Shale
COAL 5"
Clay
Sh
COAL 24
Dark Shale 2'
S.S.
COAL 24"
Clay Shale 2'
Clay Parting 14"
COAL 14"
S.S.
Bogart & Enger Cin.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

REPORT ON THE IRON ORES

OF

GREENUP, BOYD & CARTER COUNTIES,

THE KENTUCKY DIVISION OF THE HANGING ROCK IRON REGION,

BY P. N. MOORE.

THE IRON ORES OF THE KENTUCKY DIVISION OF THE HANGING ROCK IRON REGION.

I.

The iron ores of this region belong to the class of earthy carbonates or siderites, known also as clay iron-stone, and limonites or hydrated peroxides, which result from the alteration and oxidation of the carbonates. They are all in what may be properly called stratified deposits; for although some of them do not form connected strata, they all occupy regular, well-defined geological levels, which they hold over wide areas.

They are all found in association with the rocks of the coal measures, beginning at the base with an ore resting on the sub-carboniferous limestone.

There are occasional scattering beds of nodular ore in the shales of the Waverly formation; but they are never extensive enough in this portion of the State to be of any value.

In Kentucky, as in many other States, the ores occur in greatest abundance in the lower coal measures. There is no ore of more than local importance above this level. Some are occasionally found in the middle coal measures, and will be described hereafter; but they are by comparison of very little value, and are not largely worked, as they are inferior in quality and untrustworthy in occurrence.

The usual method of occurrence of the ores of this region is in beds or layers, although there are exceptions to this which will be described. At the outcrop, on the hillsides, where the ore has been exposed to the action of the atmosphere, it is usually a limonite; but as it is followed into the hill where it has been protected by a heavy covering, it occurs as a carbonate or siderite. This is always found to be the case where the ore has been protected from atmospheric influence.

The distance from the outcrop at which the siderite will be found, varies of course with the character of the overlying rock. Where this is a porous sandstone, the limonite will be found

extending a long distance under ground; and if it be near the top of a hill, the whole bed is sometimes found changed to limonite. If a dense, impervious clay shale overlies the ore, the siderite usually extends very nearly to the outcrop, and only a very small band or rim of limonite surrounds the bed.

Where the ore is covered by water for the most of the time, and thus protected from the air, it is usually found as the carbonate. This feature has been noticed at a number of places. Where it is comparatively dry the ore is usually a limonite; but when in a ravine, for instance, where water is constantly percolating through the rocks, keeping them saturated, the carbonate is almost always found.

These facts would seem to indicate that atmospheric influences alone effect the change from carbonate to hydrated peroxide of iron. There are, however, other facts which will be referred to further on, which seem to indicate that it cannot have been altogether effected by this means; and in spite of the seeming contradiction, it must have been assisted by the action of water.

In every instance the limonite has been derived from the carbonate; and in no case whatever has any indication or trace of a change by deoxidation from peroxide to carbonate been observed. The siderite or carbonate of protoxide of iron is the original mineral of these ore beds.

The siderites possess a dense, close structure, with the silicious and other impurities disseminated evenly through the whole mass, and a specific gravity which is much higher in proportion to the per centage of iron than it is in the limonites. This singular fact has been before stated by Andrews in the Ohio Geological Report for 1870, page 214. The limonites show an open, porous structure, with layers of different qualities of ore, and the impurities often segregated to themselves in the center of the specimen. They contain on an average a considerably higher per centage of iron than the siderites, and are much more esteemed by the iron manufacturers of this region. In fact, at the majority of the charcoal furnaces of this region, nothing but the limonite ores are used, as the

managers profess not to be able to produce a coarse-grained foundry iron from the blue carbonate ores. This is generally supposed to be owing to the presence of sulphur. Analyses show that there is usually somewhat more sulphur in the carbonates than in the limonites, which may be sufficient to account for the trouble experienced in working them; but it is also probable that the dense close structure, rendering them difficult of reduction, has much to do with the matter.

The average from a large number of analyses made by Dr. Peter and Mr. Talbutt of ores from this region, gives the relative per centages of metallic iron in the limonites and carbonates as follows:

Ores.	Limonites.	Carbonates.
Limestone ores	46.22	33.60
Upper block ores	44.60	34.42
Lower block ores	33.50	29.73

It will be seen from the above that the average per centage of iron in the limonites is considerably greater than in the carbonates. The specific gravity of the carbonates, as already stated, is higher, in proportion to the amount of iron present, than that of the limonites.

We thus have the singular fact presented of the carbonate ores gaining in the per centage of iron in the change to limonite, while the specific gravity, which is commonly supposed to be somewhat proportional to the per centage of iron, becomes considerably less. This is a fact which is not thoroughly understood and appreciated by the purchasers of ore in this region. They do not realize that the carbonate ores will not yield as much in proportion to their weight as the limonites, and that it is poor economy to pay the same price per ton for both.

THEORY OF FORMATION.

It is generally agreed by geologists that these ores are deposits from aqueous solution, laid down by chemical action.

There seems to be no doubt of this whatever. There are, however, different theories held in regard to the method and

time of this precipitation, and as to the condition of the ore when first deposited. The feature for which it is most difficult to account, is the occurrence of the ores as carbonates.

Under the circumstances at present prevailing, we should expect the ore to be precipitated from solution as a peroxide.

The waters which originally held the iron in solution must have been of wide extent, for we find some of the ores extending over large areas, sometimes covering hundreds of square miles; but whether these waters were oceanic in character, or large, shallow, fresh water lakes, is not well settled. It seems probable, from the occurrence of certain plant remains which are occasionally found in the ores, that the waters were shallow and fresh; but, on the other hand, there are occasional organic remains which are apparently of marine origin. Whence also the oxide of iron was derived, which the waters afterwards spread in so even a coating over the bottom, must be left to conjecture. It is a problem of no small difficulty to account for its so general dissemination and subsequent regular deposition. One theory holds, that the ore beds have all been deposited originally as peroxide of iron, and subsequently changed to carbonates, through the agency of the carbonaceous matter of the interstratified coal beds, and that disseminated through the associated shales and clays.

This theory has in its favor the fact that it is based upon a precipitation of the iron in the condition which we should reasonably expect it to assume; and there is no doubt that carbonaceous matter is competent to effect the change from peroxide to carbonate; but whether it would do so in such great masses, and over so wide a field, is a matter of considerable doubt. Moreover, this theory requires a constant association of carbonaceous rocks with the ores such as we do not find existing in nature. We often find the ores separated by wide intervals from any rocks which contain a perceptible amount of carbon—intervals so great that no possible effect can have been exerted. It is not probable that the carbon of, or the carbonated gases emanating from, a coal situated at a distance

above the ore, can have had any influence upon it; and this is the relative position they often occupy.

It is also extremely probable, or almost certain, if the change had been effected in this way from peroxide to carbonate, that it would not have been perfect in every instance; some local interruption would have interfered, and we should sometimes find places where the ore was in its original condition, or only partially changed to the carbonate. No such specimen, showing an alteration from peroxide to carbonate, has ever been found in this region by any member of the Survey, but in every instance it is found as the unaltered carbonate, or showing change from carbonate to peroxide.

Another theory is, that the ore beds are continental rock, pseudomorphs of carbonate of iron after limestone, or, in other words, that all these deposits were once beds of limestone—now changed to iron ore. It supposes that the iron was disseminated through the shales which had been deposited as a ferruginous mud above a bed of limestone. By a process of segregation, probably acting through the agency of carbonated waters, the ore has been separated and carried down upon the limestone, which in its turn was dissolved and carried away.

We should expect, however, under the conditions most prevalent at present, that the iron would be precipitated as the peroxide; but Bischof has shown* that carbonate of iron is pseudomorphous after carbonate of lime, and that it is deposited where free access of air is prevented through an excess of carbonic acid or other cause. Either the exclusion of the air or the presence of an atmosphere largely composed of carbonic acid must, therefore, have been the condition which enabled the deposition of the iron as carbonate.

This theory explains very satisfactorily the manner of occurrence of a certain large class of the ores of this region, known as the "limestone ores," as will be shown more fully hereafter; but it is improbable that the others can have been formed in this way. If all were thus deposited, we should expect to find them frequently changing to beds of limestone; but the fact

*Chemical and Physical Geology by G. Bischof—English edition, vol. II, 51.

is that certain of the most regular and persistent strata of ore in this region have never yet been traced to a replacement of this kind. They are occasionally found fossiliferous, and sometimes very calcareous; but they always maintain their identity as ore beds, and hold a uniformity of character and thickness such as the limestone ores do not possess. They seem to have been deposited as layers or beds of carbonate of iron in the shape and place we now find them, and before the overlying rocks were laid down. It is a matter of some difficulty to conceive of the conditions which would allow of the deposition as carbonate instead of peroxide over so wide an area; but there seems to be little doubt that it was so deposited.

Still another class, known as the nodular or kidney ores, seem to have been mixed with a great deal of earthy matter, and deposited as a fine ferruginous mud in quiet, fresh water; the iron afterwards segregating into the nodular form, and the earthy matter forming clays and shales.

We thus see that these ores vary considerably in their manner of deposition, while retaining the same general character.

This subject will be referred to again in discussing the general divisions of the ores.*

In the subsequent alteration of these ores, the change from carbonate to limonite, which is even now going on, there are two agencies which seem to share in the work—air and carbonated waters.

The evidence of the effect of atmospheric influence in this alteration has been already stated. It is one of the most powerful agencies; but there are some of the ores which have undergone a rearrangement, such as cannot have been effected by this alone. It must be the result of a solution, more or less complete, and a redeposition in nearly the same place in another chemical and molecular condition. The agent which has accomplished this is probably the same that has so often borne an important part in the original deposition, namely: water charged with carbonic acid. The change which is alluded

* For a fuller discussion of the different theories in regard to the formation of the carbonate ores, see Lesley's Iron Manufacturer's Guide, page 633 et seq.

to is shown by many of the ores, but most perfectly by certain of the upper block ores. It is the concentric arrangement of the layers of limonite, which are often fibrous and nearly pure, and the segregation toward the center of the silicious and earthy matter, which was evenly disseminated through the whole specimen before the alteration was begun. Specimens are frequent showing the change at all stages.

It seems to have taken place from the outside. The carbonated water gaining access to a specimen on all sides by means of the cracks and seams which abound in the ore, dissolves a portion of the carbonate of iron, which, not being protected from the influence of the air, is changed on the escape of the free carbonic acid to a peroxide, and deposited at once as a layer of limonite surrounding the center of carbonate. The carbonated water dissolves readily, carbonate of iron, lime, and magnesia, but has little influence upon alumina and silica. The iron is precipitated, the lime and magnesia are mostly carried off in solution, but the silica and alumina not being affected, are gradually separated toward the center, being surrounded by successive layers of limonite, until finally the iron of the whole specimen is changed to limonite, and we have a hollow ball of ore, in the center of which is a mass of silicious clay surrounded by successive layers of limonite. Of course, during the progress of this change, before it is complete, the carbonate of iron in the center grows more and more silicious. Many specimens have been found showing this to be the case, and showing the successive increase in the proportion of the silicious matter in the center as the change is nearer completed. The analyses of many of the ores in which these features are most common show a decidedly less per centage of lime and magnesia and a much greater per centage of metallic iron in the limonites than in the carbonates, thus corroborating this theory of the method of alteration. This process is of the greatest benefit to the ore; by it the per centage of iron is materially increased, sulphur, lime, and magnesia partially removed, and the silicious impurities separated in such a way, that, after calcining, they can be largely

removed by screening. It is much more complete than any artificial process. It has the disadvantage, however, of rendering the ore brittle and shelly, so that it crumbles to pieces easily after calcining, and a good deal of it is wasted as fine ore and dust.

All of the ores are not altered in this way. Many of them seem to have been acted upon by the air alone, or only slightly assisted by other causes. These show a simple oxidation; sometimes in concentric layers; but their structure is quite homogeneous, and the impurities remain disseminated through the whole mass.

They show a less increase in the per centage of iron, and no marked removal of impurities in the change from carbonate to limonite. The lower block ores are of this class more generally than otherwise, and, as shown already by the average of a number of analyses, the increase in per centage of iron in these is only about half that in some of the other ores.

.88

GENERAL DIVISION OF THE ORES.

II.

The ores of the region under consideration, which all belong to the same general mineralogical class and geological position, differ considerably, as already shown, in their external appearance, chemical composition, and the circumstances of deposition.

Three general divisions of them are recognized, and will be described under the names commonly applied to them. They are,

(*a*) The limestone ores.
(*b*) The block ores.
(*c*) The kidney ores.

These names are often arbitrarily and incorrectly applied; but they are sufficiently accurate and comprehensive for our purpose, and they possess the additional advantage, that, in their sequence, they approximately represent the geological position, as well as the external appearance.

The limestone ores are so called from their association with limestone, being usually found resting upon it.

The block ores are named from the peculiarity that they possess of cleaving into sharp, square-cornered blocks, as they are raised by the miners.

The kidney ores are so called from the shape which they usually assume.

(*a*) THE LIMESTONE ORES.

Properly speaking, the name limestone ore is applicable only to an ore which is deposited upon, or very near to, a limestone; but often the ore occurs at the same geological level, in the same position, with reference to the overlying and underlying rocks, over a field wider than the associate limestone. In this case the name is still given to the ore.

Owing to their comparative purity, uniform character, richness in iron, and the ease with which they are worked in the

furnace, these ores are valued more highly by the furnace men of this region than either of the others. They occur both as limonites and unaltered carbonates (or siderites), and each of these shows modifications which are rare in other ores.

The limonites of this division are found (1, and rarely) as lightish brown, semi-concretionary ochreous ores, and (2, more commonly) as a dense, dark red, close-grained ore, giving red streak and powder, but containing about the same per centage of combined water as the other. When of this character, it is often full of seams and crevices, which have been filled with calcite, and it is apt to adhere to the underlying limestone. This variety is known as red limestone ore, and is the most valuable of any found in this region.

The following analyses will serve to show the chemical composition of this variety of ore. In some of the specimens the process of oxidation has not been completed, and there remains a considerable proportion of carbonate of iron; but the samples were taken to represent the ore as fairly as possible, as it is actually mined and paid for by the furnace operators.

These analyses, as well as all the following, unless otherwise specified, were made by Dr. Peter and Mr. J. H. Talbutt, chemists of the Survey.

TABLE I.—LIMESTONE ORES—Limonites.

	1	2	3	4	5	6	7	8	9	10	11
Peroxide of iron	60.576	67.859	46.984	72.95	49.770	81.640	80.040	57.551	51.802	71.680	60.206
Carbonate of iron	15.623	....	7.890	....	....	....	....	....	10.594	....	....
Alumina	2.860	1.160	5.580	1.660	6.315	3.160	2.680	6.017	4.523	4.155	1.044
Brown oxide of manganese	....	.980	....	.640	.640	trace.	trace.	.130	....	.090	trace.
Carbonate of manganese	....	....	.572	....	....	....	....	....	trace.	....	....
Carbonate of lime	trace.	.120	21.240	.380	.380	.180	trace	.150	7.480	.380	.285
Carbonate of magnesia	.619	1.275	2.904	.083	.115	.919	.425	.758	.440	.050	.381
Phosphoric acid	.632	.143	.371	.500	.537	.060	.115	.057	.570	.084	.161
Sulphuric acid	not est	not est.	not est	.178	not est.	not est	.264	.105	.089	.270	.852
Silica and insoluble silicates	12.650	15.560	7.860	15.160	33.200	2.60	6.560	25.450	15.730	12.650	25.930
Combined water	*7.040	*12.903	*6.599	8.452	9.020	11.280	10.000	10.300	8.772	10.800	*11.141
Total	100.000	100.000	100.000	100.010	99.606	99.839	100.084	100.518	100.000	100.159	100.000
Metallic iron	49.995	47.501	39.025	51.070	34.739	56.148	56.028	40.285	41.357	50.176	42.144
Sulphur	....	....	....	.071	....	....	.107	.042	.035	.108	.341
Phosphorus	.276	.062	.161	.218	.234	.026	.050	.024	.231	.036	.070

*And loss.

No. 1. Sample of limestone ore from Hood's Run, branch of Tygert Creek. Ore used at Raccoon Furnace.

No. 2. Limestone ore from head of Two Lick Creek, Kenton Furnace.

No. 3. Limestone ore from Coon Fork, Kenton Furnace.

No. 4. Limestone ore from Shover Drift, Kenton Furnace.

No. 5. Limestone ore from Powder Mill Hollow, Kenton Furnace.

No. 6. Limestone ore, cabinet specimen, best quality, Boone Furnace.

No. 7. Limestone ore, cabinet specimen, picked to represent the best by Mr. A. R. Crandall, Assistant of the Survey, from land of S. Warnock, Tygert Creek.

No. 8. So-called slate ore, occupying the place of the limestone ore, ridge between Cane Creek and Wilson Creek, Hunnewell Furnace.

No. 9. Limestone ore from Hood's Creek, Bellefont Furnace.

No. 10. Limestone ore from the Graham bank, near Willard, Carter county; average taken from the stock bank at Willard.

No. 11. Limestone ore from Brush Creek, Pennsylvania Furnace property.

All of the above analyses, with the exception of Nos. 6 and 7, were made from average samples taken by myself.

It will be seen that in the average samples the per centage of iron varies from 34. to 51. Silica, alumina, lime, and magnesia are present in exceedingly varied proportions. Silica and alumina are always present in appreciable quantities, but the lime and magnesia vary exceedingly. The amount of sulphur is small; so small as to have little or no influence upon the ore, unless, perhaps, in the case of No. 11.

The amount of phosphorus varies widely, and in some ores is present in sufficient quantities to make a "cold-short" iron.

The unaltered carbonates or earthy siderites occur (1) as amorphous, dense, close-grained ore, varying in color from light brown to dark blue, and commonly known as "blue limestone ore," and (2) as a light-colored, coarse-grained oölitic ore called "grey limestone ore." It consists of grains of siderite, embedded in a light-colored silicious matrix. It is more commonly found associated with the ferriferous than with the sub-

carboniferous limestone. It is highly valued and much used; but it is apt to become suddenly poor in iron and very calcareous, and the character of the ore is such that this change cannot be readily detected by the eye.

The following table of analyses will show the composition of some of the limestone ores, siderites, of this region:

TABLE II.—LIMESTONE ORES—Siderites.

	1	2	3	4	5	6
Peroxide of iron. .	4.410	5.945	27.296	26.240	12.784	31.544
Carbonate of iron .	61.220	65.018	44.242	27.511	32.285	30.708
Alumina .	2.260	1.060	1.560	9.021	11.968	1.779
Carbonate of manganese. .	.150	2.332	.842	.270	.465	.060
Carbonate of lime . . .	4.480	2.720	6.580	2.320	21.125	2.730
Carbonate of magnesia.	trace.	9.038	1.046	2.838	.691	.144
Phosphoric acid.	.313	.255	.732	.499	.377	.421
Sulphuric acid	not est.	1.280	4.587	.116	.267	.491
Silica and insoluble silicates.	21.260	10.260	11.160	25.180	19.730	25.430
Combined water and loss.	5.367	2.112	1.955	6.005	.308	6.523
Potash. .	.231	. .	. . .	. . .	. . .	. . .
Soda	.309		. .	. .	. .	. .
Total.	100.000	100.000	100.000	100.000	100.000	100.000
Metallic iron. .	32.577	35.549	40.465	31.598	24.591	36.627
Sulphur. .	.	.533	1.855	.046	.107	.196
Phosphorus. . .	.136	.111	.319	.217	.164	.184

No. 1. Limestone ore from Old Orchard diggings, Boone Furnace, Carter county. Average sample from the whole bed exposed.

No. 2. Ore from Horsley bank, Boone Furnace. Analysis of a cabinet specimen of the undecomposed carbonate,

No. 3 Average sample from the ore at Horsley bank, Boone Furnace. Only a comparatively small amount of ore was accessible at this point, and it is not unlikely that it may have been unusually sulphurous—more so than the general average of the bed.

No. 4. Blue limestone ore from bank of Tygert Creek, about two miles above Iron Hills Furnace, Carter county.

No. 5. Grey limestone ore from J. P. Jones's drift, near Ashland, Boyd county. Average sample; ore at this place much more calcareous than usual.

No. 6. Grey limestone ore from Mt. Savage Furnace, Carter county. Average taken from ore at the stock pile by Mr. J. A. Monroe, aid of the Survey.

These analyses show a much greater and more constant proportion of lime and magnesia than in the limonites. Sulphur and phosphorus are also somewhat larger.

GEOLOGICAL POSITION.

The limestone ores occur at several well-defined levels; but there are two beds of greatest importance. The first is also the lowest ore of this region. It rests upon the sub-carboniferous limestone, at the base of the coal measures of eastern Kentucky. The other ore rests upon a limestone which has been called the ferriferous limestone by Andrews in the Ohio Geological Reports—a name which will be retained. In addition there are several small beds of minor importance which occur above the ferriferous limestone, but they are of local range, and have small value compared with the others. They will be referred to hereafter. The ore of the sub-carboniferous limestone will be known as the lower limestone ore; that of the ferriferous limestone as the upper or ferriferous limestone ore. The special description of each of these beds will be given hereafter; but this much of a description has been given here, as it is necessary in order to properly discuss the geographical range of these ores, and to the correct understanding of the position of the other ores to be described.

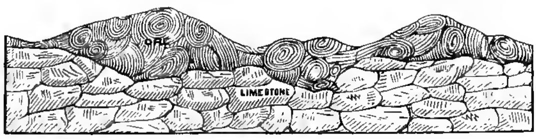
The limestone ores present a greater variation in thickness, and more sudden changes, within a short distance, than any other ore of this region. They vary in thickness from a few inches to as many feet; but the rule usually holds, that the thicker the "pocket" or "roll," the less is its horizontal extent.

There are, however, marked exceptions to this, as, for instance, at Boone Furnace, in Carter county, where, at the head of Grassy Creek, on the ridge forming the divide between the waters of Tygert and Kinnikenick Creeks, the limestone ore occurs very regularly from fifteen inches to two feet in thickness, and often much thicker, in wide pockets. At the Graham

bank, near Willard, Carter county, this ore is found in the usual rolls, some of which measure two to four feet in thickness.

The limestone upon which the ore is deposited presents an exceedingly uneven surface, being full of ridges and depressions.

Into them the ore seems to have settled in greatest quantity, growing thicker over the depressions in the limestone, and thinner over the ridges, until the top of the ore often presents a series of ridges and hollows which are the reverse of those in the limestone. The following sketch will show this feature:



At some places it might be supposed that the ore had flown into the pre-existing irregularities of the limestone in the plastic condition of a recent chemical precipitate. This supposition might explain the fact if we found the top of the ore presenting an even surface; but this is rarely if ever the case. It is usually uneven and irregular, as shown in the cut above.

This supposition is therefore probably untenable. The more probable theory of formation of the limestone ores is, that they have been formed, in most cases, by a segregation of the iron from the shales and clays above the limestone after their deposition. The iron in the form of a carbonate, held in solution by strongly carbonated waters, has been carried down and deposited upon the limestone, which was partially dissolved and carried off by the waters which deposited the iron, thus forming the depressions and irregularities in its surface which have been already described.

This theory of deposition by segregation from the overlying rocks accounts most fully for the following marked peculiarities of the limestone ores; the irregularities of thickness; the tendency to become suddenly calcareous, or to disappear altogether, giving place to a limestone; the comparative freedom from coarse silicious impurity, and the fact that an increase

in thickness is not, as in the block ores, accompanied with a corresponding deterioration in quality and increase in the proportion of sand intermixed,

It furthermore explains the presence of the thick beds of fire-clay in which barely a trace of iron remains, which are so often found above these limestone ores. Marked examples of this occur at Amanda Furnace and on Pea Ridge, between Hunnewell and Pennsylvania Furnaces.

The most common impurities of these ores, which serve to lessen their value at places, are chert (or flint) and lime.

The chert is more commonly associated with the lower limestone ore, which rests upon the sub-carboniferous limestone, than with the ore of the ferriferous limestone. Where present, it is of great injury to the ore; for a very small per centage of chert interferes seriously with the easy working of the ore in the furnace. Lime, on the other hand, is of no injury, save that, by acting as a diluent, it reduces the per centage of iron. The variation in the per centage of lime present is very great, and the change from a rich ore to one more calcareous, from a calcareous ore to a ferruginous limestone, takes place very suddenly. This change is more apt to occur in the siderites than in the limonites; for the agents which have effected the alteration of the ore seem to have also removed the greater proportion of the lime present.

Much of the low-grade calcareous ore, yielding from fifteen to twenty-five per cent. of iron, is now refused by the furnace managers at any price, for the reason that, although they know it could be used profitably as a substitute for limestone as flux, they have no cheap and ready means of determining its value. Another reason is, that the ores vary so suddenly in composition that the proper proportion to be used in the furnace charges would be constantly subject to change. Their value can only be accurately determined by often repeated chemical analyses; and as yet there are no facilities in this region for having such work cheaply done.

There are large quantities of these low-grade limestone ores, or ferruginous limestones, now either left unmined or

thrown away in selecting the ore, which, had each furnace the means to cheaply and quickly determine their value, could be made a source of profit.

(*b*) THE BLOCK ORES.

The feature which gives the name to these ores has been already stated. They occur in regularly stratified beds at certain well-defined geological levels, with a uniformity and persistence which is much greater than in either of the other classes of ore. The different beds maintain a remarkably uniform character and thickness over large areas, presenting few of those sudden changes which are so characteristic of the limestone ores. Some of them hold their quality, thickness, and geological position over a large territory, hardly varying forty feet in distance from a given datum, or six inches in thickness in many square miles. The beds vary greatly among themselves in quality and thickness; having for common characteristics the feature to which they owe their name, their cleavage into cubical blocks, and the fact that the most common impurity is silicious matter in the form of coarse sand mechanically intermingled.

The beds of ore usually occur resting in clay and bituminous shales; sometimes upon a coal, and sometimes with a sandstone overlying.

Often a series of kidneys, nodular masses or segregations of ore, is found in the shales above the bed of block ore, lying thickest close to the bed, and growing thinner above. When this is the case, the kidneys are usually of better quality than the block ore. More rarely the place of the bed or plate of block ore itself is occupied by a series of these kidneys, lying regularly at the proper level, but not forming a connected layer. The beds of ore seem to have been deposited after the underlying rock, and before the overlying, while the kidneys segregated, perhaps at the time, perhaps afterward, from the ferruginous mud which formed the overlying shale. It is a noticeable feature of the block ores that an increase in thickness is usually accompanied with an increase in the

amount of sand intermixed. This fact is so general, that it can almost be taken as a rule, with few exceptions, in judging the value of block ores—the thicker the bed the leaner and more sandy the ore, and vice versa, the thinner the bed the richer the ore. It seems that the amount of iron held in solution by the waters of deposition at each level was constant, and where deposited quietly, the resulting bed of ore was thin and comparatively pure; but where the water was disturbed, and held mechanically suspended silicious ingredients, it was thicker and leaner.

GEOLOGICAL POSITION.

The geological position of the block ores is between the two limestone ores already described. No block ore which is more than a local deposit of very limited range has been found above the level of the ferriferous limestone. The most reliable and valuable bed of block ore occurs at from seventy-five to ninety feet below the ferriferous limestone. Ranging from sixty-five feet below this to fifty feet above, a number of other block ores are locally found. This group will be known as the upper block ores, and the principal member of it as the mai block ore.

The next level of the most reliable block ores is about two hundred and fifty feet below, at from forty to sixty feet above the sub-carboniferous limestone, or where this is wanting, the Waverly sandstone. There are a number of block ores near this level, some as low down as fifteen feet above the limestone, and some extending as high as one hundred and twenty-five feet.

These will all be known as the lower block ores. At other levels there are occasional beds of ore, but they are usually local, and will be described by their local names.

The block ores, like all the others of this region, are found as limonites and unaltered carbonates or earthy siderites. The different beds vary so greatly in appearance and chemical composition, that a general description cannot well be given here, but must be left to the discussion of the separate beds.

When unaltered carbonates, the appearance of ores from the different beds does not vary much, save as the presence of more or less coarse sand gives them the "rough" appearance. After their alteration to limonite, however, they appear very differently. The upper ores are then dense, of a dark reddish brown color, with the cubes into which the ore cleaves weathered in a spheroidal shape, semi-concretionary, and hollow, the interior of them frequently containing small stalactites of limonite, and almost always more or less silicious and earthy matter, which, before alteration, had been evenly disseminated through the whole mass, but not being soluble in the waters which dissolved and re-deposited the oxide of iron, had gradually segregated towards the center, and been surrounded by the pure limonite.

The lower ores, on the other hand, retain their cubical fracture: are dull, yellowish brown and porous, formed of a mass of irregularly curved layers of ochrey limonite, holding the silicious matter disseminated through the whole mass almost as generally as before alteration. Some of them are occasionally micaceous. Occasionally, while undergoing this process of alteration, a bed of block ore will be so completely changed as to present the appearance of, and be difficult to distinguish from, the true kidney ore. When this is the case, it is often called kidney or "kidney-block" by the miners. A bed of this kind can usually be distinguished from a true kidney deposit, to be hereafter described, by the following characteristics: 1st. The ore lies at a uniform level, while the true kidneys are often scattered through a number of feet of shale or rock. 2d. On careful examination one or two plane faces can be found on each fragment, showing the surface of contact with the adjoining ore. The block ores vary in thickness from one or two inches to several feet; but the most valuable beds, those of the best quality and of most reliable extent, are usually from four to ten inches, and occasionally thicker; but, as before noted, the additonal thickness is gained at the expense of quality, when a bed elsewhere thin becomes thick.

QUALITY.

The lower block ores, taken as a rule, are inferior to the upper, in the less per centage of iron, and the greater proportion of impurities.

The following tables of analyses, by Dr. Peter and Mr. Talbutt, will show the comparative composition of the lower and upper block ores, both limonites and siderites:

TABLE III.—LOWER BLOCK ORES—Limonites.

	1	2	3	4	5	6	7	8	9	10
Peroxide of iron	54.530	50.006	41.390	40.139	56.670	59.950	41.556	36.985	44.876	**42.56**
Carbonate of iron	....	....	....	5.731	8.538	....	....	....	....	....
Alumina	2.120	8.317	6.777	8.030	4.405	5.230	8.604	5.508	4.083	....
Brown oxide of manganese	1.380	....	.180	.422	.180	....	....	.040	.260	....
Carbonate of lime	.040	.380	trace.	.380	trace.	4.580	.180	.520	.990	....
Carbonate of magnesia	1.823	.201	.065	.254	.883	.343	....	.533	.357	....
Phosphoric acid	.908	.767	.579	.038	.337	.842	.882	.367	.166	....
Sulphuric acid	.336	.356	.154	.177	.130	.837	.851	.116	.123	....
Silica and insoluble silicates	28.360	28.820	40.380	37.220	19.480	16.600	38.160	46.760	39.080	....
Combined water	10.900	11.760	9.700	*7.609	*9.377	....	10.100	8.330	9.850	....
Total	100.397	100.607	99.225	100.000	100.000	....	100.333	99,159	99.785	....
Metallic iron	38.171	35.00	28.973	29.816	44.736	41.965	29.089	25.889	31.413	**29.792**
Sulphur	.134	.142	.066	.071	.060	.335	.340	.046	.047	....
Phosphorus	.428	.339	.252	.016	.147	.367	.358	.160	.072	....

*And loss.

No. 1. Ore from Louder's bank, near Kenton Furnace, Greenup county.

No. 2. Ore from Thompson's bank, near Kenton Furnace.

No. 3. Ore from Allen bank, near Kenton Furnace.

No. 4. Block ore from Perry's branch of Tygert Creek; east slope of Garvin Hill, near Olive Hill, Carter county.

No. 5. Block ore from the outcrop in the road, west side of Garvin Hill.

No. 6. Block ore about ninety feet above the limestone, from the old road across Garvin Hill.

No. 7. Lower block ore from Hood's Run, branch of Tygert Creek, Raccoon Furnace, Greenup county.

No. 8. Rough block ore from below the principal lower block ore, Shelf Fork of Raccoon Creek, Raccoon Furnace.

No. 9. Ore from J. Downs's Oldtown Creek, Greenup county; ore used at Buffalo Furnace.

No. 10. Rough block ore, the upper of two exposed on Darby branch of Clay Lick Creek, near Buffalo Furnace.

All of the above are from average samples taken by myself.

The analyses of the lower block ores, unaltered carbonates or siderites, are as follows:

TABLE IV.—LOWER BLOCK ORES—Siderites.

	1	2	3	4
Peroxide of iron	4.989	9.734	6.500	8.648
Carbonate of iron	62.321	47.391	44.678	54.773
Alumina	7.901	4.197	4.178	7.800
Carbonate of manganese	.121	.346	trace.	1.204
Carbonate of lime	12.000	5.220	2.230	3.780
Carbonate of magnesia	.222	7.893	1.903	3.088
Phosphoric acid	.684	.121	.204	.447
Sulphuric acid	.206	.151	.250	.298
Silica and insoluble silicates	10.740	20.230	36.880	20.250
Combined water and loss	.816	4.717	3.177	. . . . .
Total	100.000	100.000	100.000	100.250
Metallic iron	33.348	29.685	26.073	29.851
Sulphur	.082	.06	.104	.105
Phosphorus	.298	.052	.089	.195

No. 1. Blue lower block ore, near J. M. James's, Dry Fork of Little Sinking Creek, Carter county.

No. 2. Blue lower block ore, from near Wm. Everman's, on Sammy's branch of Barrett's Creek, Carter county.

No. 3. Lower block ore from Womack's bank, Oldtown Creek, Greenup county.

No. 4. Blue block ore near the place of the limestone ore, Alcorn Creek, Raccoon Furnace, Greenup county.

Analyses all from average samples taken by myself.

It will be seen, on comparison of the preceding tables, that the average per centage of iron in the limonites is 33.50 against 29.73 in the siderites. The sulphur and phosphorus are nearly the same in both, while the carbonates of lime and magnesia are much greater in the siderites than in the limonites, the other ingredients remaining about the same in both.

The analyses also show, what has been already stated, that the lower block ores are very silicious and poor in iron, in comparison with the ores of the other classes. They are also seen to be somewhat more phosphatic than the others.

The appearance and character of the upper block ores has been referred to; the analyses are here given in Tables V and VI. It will be noted that in Table V, analyses of limonites, several of the specimens contain a considerable proportion of unaltered carbonate of iron:

TABLE V.—UPPER OR MAIN BLOCK ORES—Limonites.

	1	2	3	4	5	6	7	8	9	10	11	12
Peroxide of iron....	57.09	65.657	54.703	56.279	64.577	23.396	68.928	71.502	61.316	56.84	69.27	59.349
Carbonate of iron...	....	...	17.758	11.392	....	14.972	....	...	19.435	...	...	9.599
Alumina........	4.438	4 921	2.30	4.709	not est	4.077	2.768	8.567	3.537	...	...	1.957
Br'n oxide manganese	trace.	trace.	.44	trace.	1.360	.421	.290	trace.	....	...	...	.030
Carbonate of lime...	trace.	trace.	.34	.180	.440	33.778	.680	trace.	trace.	...	...	.830
Carbonate of magnesia	.086	.040	.499	.476	.820	.968	.641	.054	.212	...	...	2.027
Phosphoric acid . .	.370	.893	.128	601	.172	.537	.249	.466	.166	. .	. .	.153
Sulphuric acid....	.391	.590	.680	.260	.151	.151	.748	.800	1.009	...	...	.302
Silica & insol. silicates.	26.760	17.780	15.958	16.930	21.23	16.240	15.240	9.030	10.780	. .	...	19.810
Combined water . .	11.100	10.740	*7.194	*9.173	*11.25	*5.463	11.100	9.500	*3.45	. .	...	*5.945
Total	100.154	100.521	100.000	100.000	100.000	100.000	100.643	99.905	100.000	...	...	100.000
Metallic iron....	39.963	45.959	46.865	44.896	45.204	23.597	48.249	50.051	48.585	39.788	47.589	45.472
Sulphur.......	.156	.236	.272	.104	.070	.070	.298	.320	.403	...	. .	.120
Phosphorus.....	.161	.391	.055	.262	.074	.224	.098	.203	.072	...	...	.066

*And loss.

No. 1. Ore from Stewart's bank, three miles west of Grayson, divide between Barrett's and Everman's Creeks, Carter county.

No. 2. Ore from "Potato Knob," two miles from Iron Hills Furnace, Carter county.

No. 3. Ore from Poynter bank, Raccoon Furnace, Greenup county.

No. 4. Kidney ore associated with the main block ore, Buffalo Furnace, Greenup county.

No. 5. So-called "Kidney Block" Ore, McAlister Point, Buffalo Furnace.

No. 6. So-called "Lime Ore," the main block ore locally thickened and very calcareous, hill three quarters of a mile southeast of Buffalo Furnace.

No. 7. Ore from Little Martin bank, Laurel Furnace, Greenup county; average sample by Mr. J. A. Monroe.

No. 8. Ore from old Mt. Tom, near line between Greenup and Carter counties; ore used at Laurel Furnace; average sample by Mr. J. A. Monroe.

No. 9. Ore from Kibby diggings, divide between Lost and Tygert Creeks; ore used at Laurel Furnace; average by Mr. J. A. Monroe.

No. 10. Ore from Brushy Knob bank, Laurel Furnace.

No. 11. Ore from Osenton bank, Laurel Furnace.

No. 12. Ore from Stinson Creek, known as the "Stinson Creek Little Block Ore;" average sample by Mr. J. A. Monroe, taken from the ore at Mt. Savage Furnace stock pile.

All of the above analyses were from average samples taken by myself, where not otherwise specified.

TABLE VI.—UPPER OR MAIN BLOCK ORES—Siderites.

	1	2	3	4
Peroxide of iron	.204	13.468	.276	21.270
Carbonate of iron	78.722	55.258	66.854	33.321
Alumina	2.746	.670	4.260	4.991
Carbonate of manganese	.421	.060	.572	trace.
Carbonate of lime	2.250	4.880	2.460	.980
Carbonate of magnesia	.380	4.528	4.086	.439
Phosphoric acid	.505	.368	.709	.434
Sulphuric acid	1.160	1.043	.885	1.208
Silica and insoluble silicates	11.340	15.660	18.360	31.730
Combined water and loss	2.272	4.065	1.538	5.627
Total	100.000	100.000	100.000	100.000
Metallic iron	38.146	36.103	32.466	30.975
Sulphur	.524	.416	.354	.483
Phosphorus	.220	.200	.308	.189

No. 1. Blue kidney ore taking the place of the main block ore; drift one mile southeast of Laurel Furnace, Greenup county.

No. 2. Main block ore, Baker bank, Laurel Furnace.

No. 3. Wilson Creek blue block ore, Wilson Creek, Carter county; Star Furnace property.

No. 4. Blue block ore near Amanda Furnace, Greenup county.

All the above analyses from average samples taken by myself.

The analyses show that the high value which is given to these ores by the furnace men of this region is well deserved. They compare favorably with any found in this region.

(c) THE KIDNEY ORES.

The kidney ores are nodular masses of ore, both limonite and siderite, which are named from the shape which they most commonly assume. They are found scattered through the shales and sandstones, at various levels, all through this region, but are by no means uniformly disseminated. They do not form a continuous bed or layer of ore, save in rare instances; but, on the other hand, they frequently occur at certain clearly defined geological levels, and hold the same position over a large territory. When occurring this way they are usually scattered through from three to six feet of shale or sandstone. Such is the uniformity and persistence of some of these ores, that they serve as geological data from which to determine the position and identity of other strata of ore or of coal. As an instance of this, the two kidney ores, which serve to mark the place of the well-known Coalton (No. 7) coal, may be mentioned. These are among the most trustworthy and persistent ores of all this region.

The kidneys or nodules vary greatly in size, though there is a certain uniformity in those of each level; so much so, that local names are applied to the different beds, from the size of the kidneys, and they are known among the diggers as "Little Yellow Kidney," "Big Red Kidney," &c. Individual nodules are often found of large size—several hundred pounds in weight. In shape there is also great variation, but the most prevalent form is an ellipsoid, considerably flattened, with length about twice the breadth and three times the thickness. They often assume a variety of fantastic shapes, and it is noticed that the tendency to assume these is more marked in those which are found in crevices in sandstone than in those which lie bedded in shale.

These ores are not, as the so-called "Kidney Block Ores," already referred to, the result of the alteration and partial destruction of a bed or stratum of ore, but each individual nodule seems to be the result of separate deposition. They are formed by chemical action, which segregates the carbo-

nate of iron from the surrounding material, and, by a process of aggregation or concretion, deposits it around a given center.

This tendency of a substance to separate to itself and form concretions, is of very common occurrence in nature in other materials besides iron ore. In fact, it may be said that it exists in all rocks which are the result of chemical deposition in contradistinction to those which are mechanically deposited. In some concretions a foreign substance often forms the nucleus around which the material is deposited; but although I have diligently examined, I have never, in the hundreds of specimens which I have broken open, found a single well-marked nucleus in one of these nodules of iron ore of this region. They are of homogeneous structure throughout.

The nodules of ore very commonly show weather-cracks running all through them, and forming various fantastic figures on the surface. In these crevices various foreign substances have been deposited. The most common of these is carbonate of lime, but dolomite, gypsum or sulphate of lime, and blende or sulphide of zinc, also are occasionally found.

Occasionally there is found at the bottom of one of these beds of kidney ore, using here the word bed to mean the whole series of kidneys at one level, scattered in the associate rock as already described, a solid layer or plate of block ore, but it is always exceedingly irregular, and can never be relied on to extend any distance.

This bed of ore seems to have been deposited where the amount of iron was greatest and the waters least disturbed, and, like the block ores, it was deposited before the overlying shales

The nodules proper seem to have separated from the ferruginous mud or sand which held the disseminated oxide of iron, perhaps simultaneously with its deposition, perhaps afterward. It is not unlikely that the separation or segregation of the ore took place soon after the mud or sand was deposited, and before a great weight of overlying rocks had compacted them

so that the separation would be difficult. That the kidneys were formed in some cases after the associate rock was deposited, seems to be pretty certainly proved by the fantastic shapes which they show when filling crevices in sandstone—forms apparently the resultant of the tendency of the ore to assume its normal form, prevented by the shape of the crevice.

GEOLOGICAL POSITION.

Occasional deposits of kidney ores are found, at various levels, in the western part of this region, in the lower rocks of the geological series, but they are usually small and of no value, as they do not exist in sufficient quantity to be worked economically.

The first exception to this rule occurs in the shales above the main block ore, at numerous places west of Little Sandy river. At most of the banks here there is more or less kidney ore overlying the main block ore, and mined with it; but it is subject to great irregularities, and is not very reliable.

It is not until we approach the level of the ferriferous limestone that we find the kidney ores especially valuable. Twenty feet below this limestone occurs an ore which is sometimes a continuous layer or bed of block ore, and sometimes a characteristic kidney ore. It is known by a variety of names, such as "Lime Kidney," "Slate Ore," &c., and is the lowest kidney ore of value. The horizon of the reliable kidney ores may be said to begin about fifty feet above the ferriferous limestone. Below this level, with the exceptions noted, there is no kidney ore of any value. Above this level there is very little except kidney ore of value. There are a few local ores, somewhat similar to the limestone ore, and usually called limestone or bastard limestone ore, but they are not in any great quantity, and, in comparison with the kidney ores, amount to nothing.

Beginning, then, forty to fifty feet above the ferriferous limestone, the kidney ores are found up to about one hundred and fifty feet above. In this distance from three to six beds

of kidney ore are found. From these probably from one half to two thirds of all the native ore used in this region is obtained. It will thus be seen that these ores are of the greatest importance. Accurate statistics, to prove the above statement as to the relative amount of kidney ore mined, it is impossible to obtain, for the reason that the purchasers of ore do not all keep a record of the amounts of ore of each kind received; but it is believed not to be far from the truth.

There is no reliable ore, or ore of more than local extent and value, found above the kidney ore horizon in this region.

The kidney ores, like all the others, are found in all stages of transition from the carbonate to the limonite. The change goes on from the outside in concentric layers, and the surface of these is usually of a bright yellow color, save in some of the beds, which are more calcareous, and weather to a red color.

The quality of the kidney ores is uniformly good; they do not yield so well in the furnace as the limestone ores, or some of the best block ores, but they do not, on the other hand, present such variations in quality as the block ores. The yield in the furnaces, which use these ores almost exclusively, is from thirty to thirty-five per cent., with perhaps an average of thirty-three and a third. The yield of iron is very much reduced by the large amount of adhering dirt and clay, which is more in these than any other ores, owing to the fact that so many of them are small, and surrounded on all sides by the clay, from which it is impossible to entirely free them.

The following analyses show the composition of some of the kidney ores. Although they were all made from samples taken to represent as nearly as possible the average quality of the ore, yet it will be seen that the average per centage of iron, as shown by these analyses, is 42.39, or about nine per cent. greater than the actual yield of the ore in the furnace. This discrepancy is due mainly to the cause above referred to—the presence of clay and dirt with the ore as it goes into the furnace, which was not taken with the sample for analysis in as great proportion as it is when it goes into the furnace:

TABLE VII.—ANALYSES OF KIDNEY ORES.

	1	2	3	4	5
Peroxide of iron	61.344	56.022	58.960	54.055	66.200
Carbonate of iron	.....	8.821	.....	.....	.....
Alumina	4.236	7.191	7.284	4,919	3.907
Brown oxide of manganese	.....	trace.	.380	.420	.030
Carbonate of lime	.750	2.520	.430	.080	.430
Carbonate of magnesia	.208	1.271	.227	trace.	.345
Phosphoric acid	.795	.526	.376	.076	.130
Sulphuric acid	.041	.090	.206	.096	.182
Silica and insoluble silicates	21.480	13.430	21.210	30.080	16.530
Combined water	11.200	*10.129	10.800	10.450	11.730
Total	100.054	100.000	99.873	100.176	99.484
Metallic iron	42.941	43.473	41.272	37.838	46.34
Sulphur	.016	.036	.082	.038	.072
Phosphorus	.347	.229	.164	.033	.057

*And loss.

No. 1. Yellow kidney ore from Brush Creek, Buena Vista Furnace, Boyd county.

No. 2. Yellow kidney or so-called "Black Vein Ore," from Straight Creek, below Buena Vista Furnace.

No. 3. Yellow kidney ore sampled from a number of localities on the Star Furnace property, Carter county.

No. 4. So-called black kidney ore, from hill back of Star Furnace.

No. 5. Yellow kidney ore from Mt. Savage Furnace, Carter county; average sample selected from the ore at the furnace stock pile by Mr. J. A. Monroe. With the exception of the last, all the above analyses are from average samples taken by myself.

GEOGRAPHICAL RANGE OF THE PRINCIPAL ORE DIVISIONS.

In discussing the range or extent of territory over which the ores under consideration will be found to occur, only that area is considered where the ore is found above the drainage.

The lower ores probably occur at the proper level under the upper, all through this region; but most of them are of such a thickness that at present they cannot be profitably mined under ground by shafting.

In fact, under the present system of mining by stripping, almost nothing of the ores can be counted as of value which is covered with more than twenty feet of overlying material. Improved methods of mining by drifting will, doubtless, eventually be introduced, by which many ores that are now considered as too thin to pay for drifting will be profitably worked.

In describing the area or range of these ores, the most that can be done is to give, with approximate accuracy, the boundaries of each ore field beyond which the ore or ores under consideration will not be found, except perchance in a straggling pocket or outlier. It is not intended to assert that the ore will be found everywhere within the described fields; the character of the ore beds themselves, and what we know of the manner of their deposition, would lead us to expect irregularities such as do actually occur.

The most that can be asserted is, that in the given field there is a strong probability that the ore will be found, if sought for at its proper level.

Inasmuch as the dip of the rocks in this region is gentle and regular, especially on the west, and as the western edge of the fields is usually marked by some well-defined topographical feature, the boundaries of several of the ores lying close together will often be found to be nearly coincident.

The area of each principal ore division will be described here, without reference to the fact that the ores overlap each other, and that sometimes all these varieties of ore occur in the same area.

In showing the ore fields on the map, however, a different system will have to be adopted, which will be described hereafter.

THE AREA OF THE LIMESTONE ORES.

1. The lower limestone ore.

This ore, as already stated, is found resting upon or near the sub-carboniferous limestone, in the western part of this region. It is not, however, always present where the lime-

stone is; and when found, it varies greatly in thickness. This ore, as well as the upper or ferriferous limestone ore, is exceedingly erratic in its deposition, often being absent over large areas where it should be found.

It lies in a belt or zone of which only a portion is shown in the map, extending in a southwesterly direction, the course of the strike of the rocks.

It is not found in any quantity north of a line drawn west from Bennett's Mills on Tygert Creek. North of this, to the Ohio river, there is little ore found of any kind, except occasionally some block ore.

The western limit of this ore is the ridge forming the divide between Tygert and Kinnikenick Creeks. The ore here is found in the very tops of the hills. Of course, when this is the case, only a very small portion of the whole surface is underlaid by the ore; but in this ridge some of the largest and most reliable deposits are found. Those of Boone Furnace, already referred to, are in a spur of this ridge.

This ore extends as far south as our observations have gone; some distance beyond the field of this map, as far as the southern edge of Carter county; and it is known to extend much further. It has been found in considerable quantities around Olive Hill, Carter county, and in the divide between Tygert and Triplett Creeks.

On the east, it is found no further than the western slope of the divide between Tygert Creek and Little Sandy, which is, as will be seen on consulting the map, but a short distance from Tygert Creek; the drainage area of Tygert on the east being small and the hills very steep.

The limestone occasionally occurs east of this, on the Little Sandy slope, as at Bull's Eye Spring on Barrett's Creek, and on Oldtown Creek, but the ore is not usually found in contact with it.

An ore is occasionally found on the Little Sandy slope, which has nearly the same position with reference to the overlying block ores, and is near the Waverly sandstone; but the limestone is wanting, and the ore has the character of a

block ore of medium quality. No. 4, of Table II, analyses of block ores, shows the composition of one of these.

2. The upper or ferriferous limestone ore.

This ore occurs more brokenly and irregularly than the lower ore. Its area is extremely difficult to describe, for, in addition to the irregularity of the ore deposit, the boundary of the field, until we get some distance back from the Ohio river, is not marked by, or coincident with, any prominent topographical feature. The limestone which gives name to this ore is very irregular, and the ore is found often at its proper level where there is no limestone below. Unlike the other, however, it retains a good quality and is still highly valued, but it is apt to be thin.

The northern or northeastern boundary of this ore field is the Ohio river. Its western limit begins on the Ohio river, about a mile below Amanda Furnace; runs nearly west to Caroline Furnace; from there, southwestwardly, passing a little north of old Kentucky Steam Furnace; then south, crossing East Fork of Little Sandy, and following the main divide between Little Sandy and East Fork in a course a little west of south, passes Pennsylvania Furnace and extends out on the spurs of the main ridge toward Little Sandy. From the head of Sandsuck Creek, at the Pea Ridge banks, it follows the ridge between Cane and Williams' Creeks, passing close to Hunnewell Furnace, leaves a few detached outliers on the ridge between Wilson and Cane Creeks; passes around near the head of Wilson Creek, turns more to the west, crosses Stinson Creek and Little Fork of Little Sandy, near the mouth of Straight Creek; follows the divide between Little Fork and Little Sandy river, nearly or quite to the head of Little Fork, where it passes into Lawrence county. This region is not much developed, but enough has been done to prove the presence of this ore beyond doubt.

Toward the east the ferriferous limestone thins out quickly, and we uniformly find the ore extending further in that direction than the limestone, but gradually changing its character and disappearing. The limestone itself is not found in any

thickness on the Williams' Creek side of the ridge. The eastern boundary of the ore is approximately as follows: beginning at the Ohio river, back of Ashland, it follows Little Hood's Creek to its head; crosses in a southwest course to East Fork, near mouth of Williams' Creek; up Williams' Creek to mouth of Rush; then along the ridge between Rush and Williams' Creek; then down into Straight Creek, which it crosses about two miles above the Mt. Savage Furnace; then west of south to the mouth of Lost Creek, and thence nearly south to the county line at the head of Dry Fork. The dip of the rocks in the Little Fork valley, near Willard, is very rapid to the east, so that the area of this ore, which is regular and of very good thickness, is quite narrow in an east and west direction.

In all this area the limestone is very irregular, and from Hunnewell Furnace south to Mt. Savage, especially so. Occasional patches of small extent are fouud near Mt. Savage, and further south it is much more abundant and regular. From Pea Ridge, between Pennsylvania and Hunnewell Furnaces, north toward the Ohio river, it is much more regular in its occurrence

As one kidney ore occurs only twenty feet below this limestone, and another, the first one of the great beds of kidney ore, only from forty to fifty feet above, it will be seen that a large portion of the above described field contains the kidney ores as well, and that the western border, as described, is nearly the border of the kidney ores.

THE AREA OF THE BLOCK ORES.

1. The lower block ores.

To the west of Tygert Creek the lower block ores extend over nearly the same area as the lower limestone ore. They are found nearer to the Ohio river, reaching north of the limit of the limestone ore, although not in very great quantity. It is a fact noted by Sidney S. Lyon, of the former Geological Survey, that the ores seem to thin out toward the Ohio river. With all the lower ores this is true, and no ore, until the upper

limestone ore is reached, is found to extend in as great abundance to the river as it is further back.

From about two miles above the mouth of Little Sandy a strip, which is comparatively bare of ores, reaching three or four miles back, extends down the Ohio river to the western edge of Greenup county. In this, occasional deposits of block ore are found, and it will be considered as a block ore field, though not of great value. This thinning out of the ores is probably due to the great thickness of sandstones which occur here, marking a former region of waters disturbed by currents which deposited the coarse sandstones and interfered with the deposition of the ores.

With these qualifications in regard to the region near it, the Ohio river will be considered as the northern limit of the lower block ore field.

The northern boundary is almost the same as that of the lower limestone ores, for as one of the most widely deposited of these is usually only about forty to fifty feet above the limestone, it will not disappear toward the west much sooner. The block ore is found on the ridge between Tygert and Kinnikenick Creeks, near the corner of Lewis, Rowan, and Carter counties, where it is some fifty to seventy-five feet below the top of the ridge.

Further northeast, at Boone Furnace, it is held only by the very highest points in the ridge, and still further northeast, near Kenton Furnace, it is last seen in the spurs running out toward Tygert Creek before the main ridge is reached. This is also the case in the region at the head and to the west of Shultz Creek. The ore is also wanting in the region immediately south of Springville.

On the south the lower block ores extend uninterruptedly to Barrett's Creek and the head of Little Sinking, and are also found near Little Sandy, about five miles above Grayson. Whether they will be found in the drainage of Big Sinking and the lower part of Little Sinking Creeks, as well as in all the heavy conglomerate region in the valley of Little Sandy to the south, is a question yet unsettled. It is not unlikely that they

are wanting, the place for them being occupied by the heavy conglomerate sandstone.

The eastern boundary of these ores may be approximately given as the Little Sandy river. Although they are occasionally found further east, yet they are not abundant, and not much, if at all, worked at the present time.

2. The area of the upper block ores.

With the same qualifications in regard to the region near it, as was made in the case of the lower block ores, the Ohio river is given as the northern boundary of the upper block ores.

The western boundary is the divide between the waters of Little Sandy and Tygert Creek.

To the south these ores have been found almost to the southern edge of Carter county. There is, however, a large region west of Little Sandy, and south of Little Sinking Creek, where little or nothing is known as to their presence. There has been no development in this locality, as there was no market for the ore, nor means of getting it out readily.

The eastern boundary does not differ very greatly from that of the upper limestone ore already given, for while the block ores average from eighty to one hundred feet below the limestone, and would pass below the drainage some distance before it to the west, yet the limestone ore thins out and disappears on the east, about the same place that the block ores pass under the drainage. It is sufficiently approximate, therefore, to consider it the same.

THE AREA OF THE KIDNEY ORES.

The northern boundary of the kidney ores in this region is the Ohio river.

The western is nearly the same as that just given as the boundary of the upper limestone ore. Where the boundary is any prominent topographical feature, it is usually the same for both limestone and kidney ore, as the distance between them is only from forty to fifty feet. Where, however, the ores run out toward the west on the spurs of the main ridges, the limestone is usually found from one to two miles further

west than the kidney ore. In the extreme southern part of Carter county this ore has not been much developed, but it is known to extend nearly to the Lawrence county line.

To the east the kidney ores extend much further than the limestone. There is an area of many square miles in which they are almost the only ores of any value. They are found along the Ohio river to the mouth of the Big Sandy or Chatterawha river, and up that stream in greater or less quantities, being considerably interrupted by the heavy sandstones which there abound, to the mouth of White's Creek. From here the line runs a little south of west, crosses East Fork near the mouth of Garner Creek, holding the same course to the head of Garner Creek and a little beyond. It then turns more to the south, crossing Straight Creek about two miles below its head, Lost Fork about three miles above its mouth, and thence nearly south or a little southeast to the limits of the map. In the region to the south and southeast of this line, between it and Big Sandy river, the kidney ores are for the most part carried below the drainage by the dip into the Bolts' Fork or East Fork basin. At some places the level of the ore in this region is above drainage, but its place is occupied by one of the heavy sandstones which are so abundant here.

DESCRIPTION OF INDIVIDUAL ORE BEDS.

III.

Having now seen the general features of the ores of this region and their general classification, a brief description of each of the separate beds, or of such at least as are of importance, will be given. This will show somewhat more in detail the character of each ore, its localities of best development, and at what furnace, if any, the ore is used. They will be described in the order of their occurrence geologically, beginning with the lower limestone ore, the first of the series.

THE LOWER LIMESTONE ORE.

The geological position of this ore has been already given in the general description. It rests upon the sub-carboniferous limestone, but is not found wherever the limestone is. Often it disappears entirely, or is represented by a thin band of ferruginous chert. Where we find the conglomerate sandstone or the coarse sandstone which represents the conglomerate, coming close down to, or resting immediately upon the limestone, the ore is much more apt to be wanting than where a considerable thickness of clay shales intervenes between. There are some marked exceptions to this rule, however, where this ore occurs of unusual thickness, with only a few feet of shales between it and the sandstone.

This ore is not found to extend at its proper level beyond the limestone, where that rock is wanting, nearly so often as the ore of the ferriferous limestone.

Its quality is shown by analyses one to seven of the analyses of limestone ores, limonites, and numbers one to four of the analyses of siderites. More than the upper limestone ore, it is apt to be injured by chert, and in the carbonate ores sulphur is sometimes present in quantity sufficient to injure it.

Taken in its general character, it is, however, a most excellent ore, and deservedly holds the highest place in the estima-

tion of the iron manufacturers of this district. It is used almost exclusively at Boone Furnace. It is also used at Kenton and Iron Hills Furnaces, from the banks in the neighborhood, and at Raccoon and Laurel, from banks on Tygert Creek, whence the ore is hauled over the divide to these furnaces. It was used at New Hampshire Furnace when it was in operation, and ore from that property now goes to Kenton. It has not been found in any quantity on the Little Sandy slope; a few deposits which occur near the proper place for it are found, but the ore has the quality and appearance of a block ore. The disappearance of this ore towards the Ohio river has been already noted. It is partly due to the thinning out and disappearance of the limestone, which is present near the river only in patches; but I am informed by Mr. Crandall, that where the limestone does occur, at the lime-kilns below Greenup Court-House, the ore seems to be wanting.

In Ohio, the limestone occurs very irregularly, and this ore is of comparatively little importance. In Kentucky, it is one of the most important and valuable ores of the State.

To the southwest, along the line of outcrop of the coal measures, it occurs in large quantities. It is found in the region around Carter caves, and in the vicinity of Olive Hill, where it seems to be reliable and of a good workable thickness. Still further southwest, in the valleys of the Licking and Kentucky rivers, this ore is found in abundance, and is mined to supply the Bath, Cottage, and Red River furnaces, producing the celebrated Red River pig iron—an iron which has a national reputation, and for certain purposes acknowledges no superior.

THE LOWER BLOCK ORES.

The first of these occurs at a distance of from fifteen to thirty-five feet above the limestone. Its position at several localities is shown by sections of plate No. 1. In quality and general appearance it does not vary greatly from the other ores of this general division.

It occurs in the neighborhood of Iron Hills Furnace, on Barrett's Creek and the head of Little Sinking, and in the

vicinity of Olive Hill. Further north it is not found, and what its extent is towards the south, is unknown. It is not found further east than about three miles west of Grayson, on Barrett's Creek.

Next above this, ranging from forty to seventy feet above the limestone, or when the limestone is wanting, above the Waverly, occur sometimes one, sometimes two beds of block ore, which are the most reliable of this whole division, and have given name and character to it. They are found all over the already described lower block ore field.

When both occur, they are usually from fifteen to twenty feet apart. It is difficult to tell, at some places, whether the lower one of these is not the same ore as that last described, with the rocks between it and the limestone somewhat thickened from its normal distance of fifteen to thirty-five feet, or whether they are separate ores. It is certain that they are both found together at very few places. The two ores just described, however, occur together at a number of places. They are known by a great variety of names, and the names are changed at nearly every locality, or else they are applied indiscriminately to both. They are called "little block," "block," "lower vein," "lower block," "rough block," "big rough block," &c., at different places, or as the ore varies in thickness and quality.

Through the southern part of this region there seems to be but one of these present, and that the lower ore. It is mined on Barrett's Creek and hauled to Grayson, whence the ore is shipped to Hunnewell Furnace. It is found also on Everman's Creek. Around Iron Hills Furnace it occurs, but is very little used, as other ore of equally good quality can be more cheaply obtained. The ore of the McCleese bank, on Tygert Creek, which has been used at both Iron Hills and Laurel Furnaces, is probably of this bed.

At Boone Furnace but one of these is known, and it occurs fifty to sixty feet above the limestone ore. [See sections at Sellard's bank and on Saw-mill branch.] It is very little used in comparison with the limestone ore.

At Kenton Furnace the block ores furnish about two thirds of all the ore received. This is all obtained from a bed fifty feet above the limestone, which is the lower one of these two. The only place where the upper ore is known is at Thompson's bank, one mile below the furnace. Here it occurs about twenty feet above, and is said to be very sandy and "rough." The ore which is mined is called "the little block." It ranges from four to ten inches in thickness, sometimes in several layers of two to three inches thick, with clay shale between. Several analyses of this ore from this locality have been given, which show its quality. The ore above the "little block" is called the "rough block" or "big rough block." This name is commonly given at Kenton Furnace to a coarse sandy ore, which occurs about one hundred feet above the limestone. It occurs at a number of places, but is hardly used at all at present. It is said to vary from six to twelve inches in thickness, but to be so sandy and so poor in iron that it cannot be profitably used at the furnace. Its position with reference to the other ores will be seen on reference to the accompanying sections. No ore corresponding to this one, fifty feet above the "little block," is known to occur at other localities.

At Raccoon Furnace and vicinity the two ores occur respectively at about forty-five to fifty and sixty-five to seventy feet above the Waverly sandstone, the limestone being usually absent. Here, however, unlike it is at Kenton, the lower ore is lean and sandy, while the upper ore is of fair quality, and is worked at the furnace in considerable quantity.

The lower ore has been very little mined lately on account of its leanness. Considerable quantities of it have been dug on Raccoon Creek above the furnace, and the benches where it has been dug show it to have occurred quite regularly. Whether it will be found at its proper level on other parts of the Raccoon property is yet to be determined. In the table of analyses of lower block ores, limonites, number eight is a sample from this bed. It is called at Raccoon the "rough block" ore.

The upper of the two ores is commonly known here as the "lower vein" ore. It has been and is still very extensively mined at a number of points on this property, on Raccoon Creek, Hood's Run, and Alcorn Creek. The benches extend for miles around the hills, keeping the proper level and serving for a well-marked datum for geological sections, as well as giving good opportunities to ascertain the dip of the rocks. The ore usually is from four to six inches thick, and of medium quality. It is apt to become thick and more sandy, and needs to be carefully watched at the furnace, in order to secure it of even average quality.

An analysis of ore from this bed is given in No. 7, of the table of lower block ore analyses. The geological position is seen in the sections of plate 2 and 3.

Near the Ohio river these ores are found, and sometimes of considerable thickness; but they are of no better quality and are quite irregular, as already stated. They have been mined at various places in the past, but not now to any extent.

At Buffalo Furnace there are two, and sometimes three, beds of these ores. The upper one is the best in quality, the thinnest, and the one which has been most used. This holds a position which seems to be considerably above the ore which is most used at Raccoon, although it is difficult to tell with certainty, for the reason that at Buffalo the distance which the ore in question holds above the Waverly cannot be accurately determined. Its position is judged by measuring downward from the main upper block ore and the No. 3 coal. Estimating in this way the upper ore of the three is thirty to thirty-five feet higher than the ore which is supposed to correspond with it at Raccoon Furnace. In quality, appearance, and thickness they are very similar.

The two ores below are thick, sandy, and lean, and very little used. They vary from ten to fifteen inches in thickness. An analysis of a sample taken from the upper of these two rough ores, the middle one of the three, is given in No. 10 of the table of analyses.

This bed corresponds very nearly in position, measuring downwards, as before described, to the main, so-called, lower vein of Raccoon; and the one still below, to the "rough block." The relative position of these ores will be seen on reference to the sections of plate No. 5.

Further south, at Laurel Furnace, we have sometimes one and sometimes two of these lower block ores. The distance between them and the Waverly is much increased, owing to the thickening of the coarse sandstone which represents the conglomerate; but the distance from the ores above remains very nearly the same, and it will be seen, on reference to the accompanying sections, that it is nearly the same as that at Raccoon.

This confirms the statement that the middle of the three ores at Buffalo corresponds to the main lower block ore. They are not largely mined at Laurel Furnace; hence hardly enough was seen to judge of their character; but they are reported to be lean and sandy.

Above the horizon of these ores just described, there has been none found which has any great range and uniformity, until the horizon of the upper block ores is reached; but there are a number of beds of ore which are of considerable importance, although they are of comparatively local extent. They will be described as nearly as possible in the order of their occurrence. It will be seen that several of them occur at widely separated places at nearly the same level, but no equivalency is inferred from this, for there has been no connection traced between them. On the contrary, they seem to have been deposited in local and independent basins.

The first in order, and most important of these, is the Lambert ore.

THE LAMBERT ORE.

On the Iron Hills Furnace property, in the ridge between Clark's branch of Tygert Creek and Buffalo Creek, is a bed of ore which is called, from the name of the former owner, the Lambert ore. It is seventy-three feet from the top of the sub-

carboniferous limestone to the bottom of the ore. The ore itself is of very unusual thickness, measuring at one face in the main opening fourteen feet ten inches. At the main opening on Clark's branch it will average from ten to twelve feet. The ore here is exceedingly clayey and ochreous; in fact, a large proportion of the bed is ochre and sandy clay, so that this great thickness cannot be counted as all available ore.

What the average proportion of good ore in the bed is, there is no accurate means of estimating. The covering of earth above the ore is very slight, so that a thorough oxidation and alteration has taken place with a separation of the most of the silicious matter from the oxide of iron. This natural process has been of great benefit to the ore, as it enables that which is sufficiently rich for smelting to be easily separated from the sand and ochre. As it is, however, a considerable quantity of this foreign matter now goes into the furnace, which could be removed by a proper arrangement for washing the ore instead of separating by hand as is now done.

At the main opening on Clark's branch this ore is seen at its best. At other places where it is found, it ranges from three to five feet in thickness, apparently thinning out in all directions. On Royster branch of Buffalo Creek it is three feet eight inches thick, but more ochreous if possible than at the main opening. Beyond this ridge, between Clark's branch and Buffalo Creek, this ore has not been found.

Its position is so nearly that of one of the lower block ores, that it seems not impossible it may be merely an extension and thickening of one of them, probably the upper of the two most constant.

The accompanying sections, No. 2 of plate 2, and Nos. 1 and 2 of plate 3, will show the apparent equivalency.

This may be merely a coincidence, however, for it is unsafe to assert an equivalency of ores at a great distance apart, unless we have more connecting links than in the present case. Against this equivalency with one of the lower block ores, we have the fact that between the limestone and the Lambert ore there is certainly one and perhaps two block

ores, one at fifteen feet, and the other reported at forty to fifty feet above the limestone.

At a number of places, at some distance from this region, ores have been found which are supposed to be the equivalents of the Lambert ore, but they are all, so far as noted, at a considerable distance above the proper level.

The great thickness of this ore, and the little expense with which it can be mined, make it a deposit of great value, even if it be of low grade, as has been commonly asserted. For the present, and so long as the ore mined is a limonite, the quality of it as it goes into the furnace will depend largely upon the way it is sorted and screened. It is so thoroughly disintegrated, and so mixed with sand, clay, and ochre, that if not carefully treated much of these impurities will go into the furnace. These with careful sorting and washing, or dry-cleaning by machinery, would be removed, to the great benefit of the ore, and improvement of the furnace working.

Where the ore is found as the unaltered carbonate, it is dense, hard, and lean, with the silicious matter, which in the process of alteration to limonite is partially separated, disseminated all through it. When it comes to working this kind of ore, it will be a matter of more difficulty to improve it by treatment before it enters the furnace, and success in using it will depend largely upon proper methods of roasting.

The area occupied by this ore has not been accurately determined, nor can it be, without a detailed topographical survey which will show the contours of the hills with accuracy. It is certain, however, that there is a quantity ample to supply all probable demands upon it for a long time to come, at prices which will enable it to be used in preference to other ores of better quality but higher price.

The following analyses show the quality of the limonite of this bed:

	1	2	3	4	5	6
Peroxide of iron	52.460	52.238	68.61	46.45	77.71	63.80
Alumina	7.304	2.833	....	....	....	....
Brown oxide of manganese	trace.	.130	....	....	....	....
Carbonate of lime	trace.	.650	....	....	....	....
Carbonate of magnesia	.155	.641	....	....	....	....
Phosphoric acid	1.224	1.679	....	....	....	....
Sulphuric acid	.268	.230	....	....	....	....
Silica and insoluble silicates	25.360	30.580	11.48	26.13	5.58	12.74
Combined water	12.360	10.650	..	....	....	....
Total	99.331	99.631	....	....	....	....
Metallic iron	36.722	36.566	47.83	32.52	54.00	44.66
Sulphur	.117	.092	.04	.04	.05	.08
Phosphorus	.534	.733	1.14	.75	.56	.73

No. 1. Average sample, by Mr. J. A. Monroe, of ore from an unroasted kiln on the stock bank, Iron Hills Furnace.

No. 2. Average sample, by myself, taken at the main opening on Clark's branch.

The above analyses are by Dr. Peter and Mr. J. H. Talbutt.

No. 3. Analysis by Dr. C. F. Chandler, of Columbia College, New York, of sample of hard ore from Smith Hill.

Nos. 4, 5, and 6 are analyses by Dr. Chandler of specimens of ore from Wilson Hill. No. 5 is hard; Nos. 4 and 6 soft ore.

The last four analyses were kindly furnished by Mr. H. W. Bates, of Riverton, Kentucky, Vice President of the Eastern Kentucky Railway. They were made from specimens selected by Mr. H. F. Q. D'Aligney, and published by him in a report upon the property of the Iron Hills Company. As to the character of the samples analysed by Dr. Chandler, nothing is stated, but it is probable that they were single specimens only, and that they represent the ore at its best.

The per centage of iron shown by the first two analyses is considerably greater than the ore is supposed to contain by those who worked it at the furnace. The impression is, that it yields a little less than thirty per cent. of iron in actual working in the furnace.

It is possible that the samples, although carefully taken, did not contain as much dirt and clay as the average of the ore; but, on the other hand, it can be said that no trial has ever been made for time sufficiently long to be a fair test, with ore, of which the weight before roasting was known, using it without admixture of other ore.

The furnace ran a few days with Lambert ore alone, but the calculation of the yield was from the weight of roasted ore, guessing at the loss which occured in roasting. The close resemblance which the two analyses bear to one another, shows at least an approximation to accuracy in the sampling, as they were made by different persons. It is not improbable, however, that they both represent the ore as a little better than it really is, for there is a constant liability in sampling ores, to take them with less adhering dirt and clay than they carry when weighed at the furnace scales.

Much of this ore after its alteration to limonite is of an ochreous semi-concretionary structure, with an outside layer of comparatively pure limonite inclosing a large core of ochre. It was a matter of some considerable interest to know the composition of this, as it is the worst of the ore. A sample was taken by carefully selecting a large number of small pieces of the ochre, excluding any of the denser, purer ore. The locality from which the sample was taken is an opening of the Lambert ore on Royster Hill. The analysis by Dr. Peter and Mr. Talbutt is as follows:

Peroxide of iron	38.285
Alumina	5.455
Brown oxide of manganese	.120
Carbonate of lime	.460
Carbonate of magnesia	.065
Phosphoric acid	1.000
Sulphuric acid	.178
Silica and insoluble silicates	44.760
Combined water	9.500
Total	99.123
Metallic iron	26.799
Phosphorus	.436
Sulphur	.071

This analysis shows a per centage of iron greater than commonly supposed, and differs chiefly from the other ore in the much greater proportion of silicious matter present.

The quality of the undecomposed carbonate ore of this bed is shown by the two following analyses by Dr. Chandler, of New York, made for Mr. D'Aligney. The specimens analyzed were both from test shafts sunk on the main Lambert Hill, but whether taken as carefully averaged samples or not, is unknown.

	1	2
Metallic iron	23.91	34.37
Silica	36.35	11.31
Sulphur	trace.	.36
Phosphorus	.75	1.23
Lime	2.50	.....

OTHER ORES OF THE LOWER GROUP.

About thirty-six feet above the base of the Lambert ore on Smith Hill, one of the hills between Clark's branch and Buffalo Creek, is a heavy block ore, twelve to eighteen inches thick, called at Iron Hills Furnace the "German ore." It is a porous, semi-oölitic ore, in the alteration of which from carbonate to limonite the silicious matters, instead of segregating in large quantities toward the center, have remained disseminated through the mass in small, white, irregular masses, rarely over one tenth of an inch in diameter, thus giving to the ore a speckled appearance, which is quite characteristic of it, and makes it appear more silicious than it really is. It is not highly valued at the furnace, where it is supposd to be quite lean.

An analysis by Dr. Peter and Mr. Talbutt, of this ore, shows as follows:

Peroxide of iron	57.557
Alumina	2.727
Carbonate of lime	trace.
Carbonate of magnesia	.065
Phosphoric acid	1.746
Sulphuric acid	.185
Silica and insoluble silicates	26.180
Water expelled at red heat	11.700
Total	100.160
Metallic iron	40.290
Sulphur	.074
Phosphorus	.762

This shows a much larger per centage of iron than is commonly supposed, and not unlikely more than the average, owing to the character of the sample, which was probably better than the average of the whole bed.

An analysis of a specimen of this ore made by Dr. C. F. Chandler, of New York, for the Iron Hills Company, and published in the report of Mr. D'Aligney upon the property of that company, is as follows:

Metallic iron	46.50
Silica	17.48
Sulphur	.12
Phosphorus	1.37

Nothing is said as to the character of the sample from which this analysis was made.

At several other places ores occur at nearly the same level as this last described.

On Garvin Hill, west of Olive Hill, Carter county, there is an ore which occurs at from ninety to one hundred feet above the limestone. It seems to be of a good thickness, although it was not opened sufficiently to tell exactly. It is of good quality, as shown by the analysis, No. 6, of the table of lower block ore analyses, limonites. What is its extent in this locality is not known; it was only seen at one or two outcrops. Above the principal outcrop of it there was much scattered surface ore, limonite of the best quality, which was not traced to its place. It may be that it is from the upper portion of

the bed just spoken of. An analysis of a hand specimen of it made for Mr. K. B. Grahn, of Riverton, Kentucky, and kindly furnished by him for publication, gave 53.9 per cent. of iron.

The so-called "big rough block" ore of Kenton Furnace, already referred to, occurs at nearly the same level as this.

An ore on Oldtown Creek, on the land of Mr. J. Downs, an analysis of which is given in No. 9 of the table of lower block ore analyses, also occupies very nearly the same geological position.

On Cumming's branch of Everman's Creek, on the land of Messrs. Means and Russell, is a deposit of hard ore which is seen, about three feet in thickness, in two outcrops at some distance apart. The ore lies in sandstone, which is thin-bedded and shaly above, coarse and heavy below. It is hard, dense, apparently calcareous, and poor in iron. It is, nearly all of it, the unaltered blue earthy carbonate, being very little changed to limonite even at the outcrop.

The analysis of an average sample taken by myself is as follows:

Peroxide of iron	9.255
Carbonate of iron	46.893
Alumina	5.703
Carbonate of lime	12.460
Carbonate of magnesia	.250
Phosphoric acid	.978
Sulphuric acid	trace.
Silica and insoluble silicates	23.530
Water and loss	.951
Total	100.000
Metallic iron	29.116
Phosphorus	.427

This analysis shows the ore, although lean, to be better than generally supposed. The considerable quantity of lime present is noticeable. By roasting properly, the per centage of iron can be raised sufficiently high in the roasted ore to certainly make it pay for working. So far it has never been tried in any furnace.

The exact geological position of this ore is not certainly determined, for the reason that in taking the section at this place, no good datum or starting point was obtained; we only know approximately the place of it. The ore is from ninety to one hundred feet above the bed of Everman's Creek, which is supposed to be not over twenty feet above the top of the limestone, and it may be much nearer. This ore is called the "fox den" ore, from the place where it was first discovered. It has never been found, to my knowledge, except on Everman's Creek. It seems, however, to be a regularly bedded deposit here, and will doubtless be found in considerable quantity.

On the same branch of Everman's Creek is an exposure of an ore, which occurs about one hundred to one hundred and five feet above that just described.

This is not the proper place for its description, for it is not next in geological sequence; but as it seems to be local, and its position is well shown in the section with the last described ore, the proper order will be in this case neglected.

The ore, so far as seen, is all limonite, of open structure, homogeneous in character, not at all inclined to be concretionary, sandy, and ochreous.

It shows a thickness of three feet six inches, and perhaps more. The analysis of it by Dr. Peter and Mr. Talbutt, made from a sample taken by myself, is as follows:

Peroxide of iron	51.623
Alumina	1.671
Carbonate of lime	trace.
Carbonate of magnesia	.483
Phosphoric acid	.081
Sulphuric acid	.408
Silica and insoluble silicates	36.830
Combined water	9.230
Total	100.326
Metallic iron	36.136
Phosphorus	.035
Sulphur	.163

This analysis shows the ore to be quite rich enough in iron to be valuable, but the per centage of silicious matter is un-

fortunately high. The ore was seen at but one outcrop, and the structure and appearance of it at this place seemed to indicate that it is a local thickening. It has not, however, been prospected enough to furnish a basis for a reliable judgment as to its extent.

Returning once more to the description of the ore beds in their proper order and to the Iron Hills property, we find occurring next above the so-called "German ore," a layer of ore which is called the "crown ore." This is also found, and found only in this region, in Smith Hill. It is twenty-one feet above the "German ore," and about one hundred and thirty feet above the top of the limestone. It is a block ore of rather better than average quality, showing the semi-concretionary structure with the curving ochreous layers, which is so characteristic of the lower block ores. It is about fifteen inches in thickness, of which the upper half is of good quality and the lower is sandy and ochreous. An average sample was taken from the upper portion of the bed for analysis, which resulted as follows:

Peroxide of iron	52.736
Alumina	3.534
Brown oxide of manganese	.320
Carbonate of lime	trace.
Carbonate of magnesia	.065
Phosphoric acid	.800
Sulphuric acid	.170
Silica and insoluble silicates	31.840
Combined water	10.700
Total	100.326
Metallic iron	36.815
Phosphorus	.349
Sulphur	.068

This shows a good workable per centage of iron, and not enough of phosphorus or sulphur to injure it, but rather too much silicious matter. As stated, this ore has been found only on Smith Hill, where it occurs about twenty-four feet below the top. Other ores which occur near this geological level, so far as they can be placed, are as follows: a bed of ore, not seen, but said to be quite thick and of very good quality, on

the Boone Furnace property, at the head of Smith's branch of Buffalo Creek, in the divide between Buffalo and Tygert Creeks; a rough block ore on the south branch of Everman's Creek; another on Elk Lick branch of Tygert Creek, above the Iron Hills Furnace property, and a block ore of good quality on Whetstone branch of Barrett's Creek. These are not much worked, and in most of the cases the thickness and quality of the ore had to be taken from the report of persons who had seen it.

On the Laurel Furnace lands, about one and a quarter miles southeast of the furnace, is a bed of ore resting upon a coal. The ore is the blue unaltered carbonate, quite sandy and lean in appearance, but it is not so much so as to render it worthless. The thickness was not seen, but it is reported to be from one to two feet. The coal below is reported to be one foot in thickness.

It is not intended to assert any equivalency in these ores; they are only described together because they are near the same geological level.

Further north, on the Raccoon Furnace lands, an ore is found a little above the position of these last described, which is called the "slate ore." It is seventy-nine feet above the main lower block ore, and about one hundred and forty-five to one hundred and fifty above the Waverly sandstone. It has been mined at a number of places in this region, on Hood's run, at the head of Raccoon Creek, and below the furnace; but to nothing like the extent of the main lower block ore.

None of the banks of this ore have been recently opened, consequently, the quality and thickness cannot be given with certainty; but the probability is, that the ore is lean or it would have been more extensively mined.

A thin block ore, only from one to two inches thick, which occurs at Laurel Furnace in the Baker bank section, occupies very nearly the same place as this last described ore with reference to the underlying block ore; but the distance to the Waverly is considerably increased. This ore has been erroneously referred to the level of the Lambert bed.

This properly closes the list of the lower block ores, but there are one or two ores of local importance which occur between this level and the upper block ores. The most important of these occurs on Raccoon Creek, on the Raccoon Furnace lands, Greenup county. Its normal distance above the main lower block ore is one hundred and thirty-five feet. It rests in clay shales, containing a considerable amount of bituminous matter, under a layer of close-grained sandstone, which is used at the furnace for hearth rock. The ore is coarse-grained carbonate of very good quality, and is remarkable for the number of casts of *stigmaria* which occur in it. The thickness is said to vary from two to twenty-four inches. It is more irregular in thickness than the block ores generally, but does not present the changes of quality which they so often show. It is known only in this vicinity; at other places it has not been found, although often sought for.

The following is an analysis of this ore by Dr. Peter and Mr. Talbutt:

Carbonate of iron	64.024
Peroxide of iron	4.044
Alumina	4.414
Carbonate of lime	1.340
Carbonate of magnesia	.836
Phosphoric acid	.217
Sulphuric acid	.563
Silica and insoluble silicates	20.310
Water and loss	4.252
Total	100.000
Metallic iron	33.627
Phosphorus	.095
Sulphur	.225

There are some other local deposits of ore in the space between the lower and upper block ore series, but they are usually poor and of small extent, and hardly worth description here. Taking the greater portion of the region west of Little Sandy, we find a space of from one hundred and fifty to two hundred and forty feet between the two block ore horizons, which is comparatively bare of ore beds. In this space most

of the local ores which have been just described occur, but it will be noticed that they do not all occur at one place; on the contrary, where one or two of them are found, the others seem to be wanting. It is possible that upon more careful and intelligent prospecting, the ores which are now supposed to be local will be found over the whole field, but there is a presumption against it.

Above this belt of non-ferriferous rocks we come to the horizon of the upper block ores. These occur at several levels, all of them within a section of one hundred and twenty feet.

The upper block ores differ from the lower in that they are usually thinner and of much better quality. They furnish to Raccoon, Buffalo, and Laurel Furnaces their principal supply of ore, and to most of the other furnaces now in operation in this region, a greater or less quantity.

There is one of these that is of the most value and the greatest regularity of occurrence, which has been called the "main block ore." This has associated with it at different places one or two other beds which, although valuable and of uniformly good quality, do not have anything like its range.

These will be first described, as the most important of them occurs at some distance below the main block. This is an ore bed which is pretty generally found over all of the upper block ore field south of Laurel Furnace. It is from two to ten inches thick, and generally of most excellent quality. Its usual distance above the sub-carboniferous limestone, or when the limestone is wanting, above the Waverly sandstone, is from two hundred and fifty to two hundred and ninety feet, and sixty feet below the main block ore. North of Laurel Furnace it rarely occurs, although it is possible that the ore which is found below the Old Tygert drift, at the head of Alcorn Creek, on the Raccoon Furnace property, may be its representative. In the immediate neighborhood of Raccoon Furnace the place of the ore is occupied by a coarse heavy sandstone. At Laurel Furnace and vicinity it occurs quite regularly. It is the ore principally mined on the ridge between Lost Creek and Crane Creek, towards Hopewell, and at Far Mt. Tom at the head of

Crane Creek. It is also found at the Stewart bank, between Barrett's and Everman's Creeks, three miles from Grayson, and at the Potato Knob bank at the head of Everman's Creek, two miles from Iron Hills Furnace. It has no local names except at Laurel Furnace, where it is called the "Hickory Flat," or "Far Mt. Tom" ore, from the localities where it is found in greatest abundance.

Its geological position will be seen from the sections showing the upper block ores in this region. About fifteen feet below the main block ore, in some of the hills between Everman's Creek and Little Sandy, is a bed of ore which is reported to be thin and of excellent quality, but it has not been found over any great area by any member of the Survey.

We come now to the principal bed of this division, the main block ore. The appearance and quality of this ore have been pretty well described in the general discussion of the ore beds, Part II, and the composition shown by two tables of analyses of samples from a large number of localities. The geological position of this ore will be seen from the accompanying sections, which show its position with reference to the rocks below. All of the first series of sections are west of Little Sandy, the region of greatest development of the block ores. Those showing the rocks above were taken on the east side of Little Sandy—some of them at a considerable distance east, where the ore has been brought by the dip of the rocks nearly to the level of the drainage.

It will be seen from these sections that this ore varies from three hundred and ten to three hundred and fifty feet above the limestone or Waverly sandstone, where that can be determined. It is from two hundred and forty to two hundred and ninety feet above the main lower block ore. A decrease in these distances will be noticed in the sections at Buffalo Furnace, where the distance is at its minimum. It is greater at Raccoon to the north, and considerably greater to the south at Laurel Furnace and beyond. This last increase is due to the thickening of the conglomerate sandstone, which is present on Oldtown Creek, at the furnace, and on some of the branches of

Everman's creek. This ore is about thirty-five feet above the No. 3 coal, and the two hold this relation over a wide area. The coal is found at Raccoon, Buffalo, and Laurel Furnaces, and at one locality on the head of Barrett's Creek; but in the most of the region south of Oldtown Creek it has not yet been discovered, but probably will be, when sought for in the proper place. East of Little Sandy, however, the coal and ore are shown together in a large number of places; and this occurrence together, often serves to identify them both, and gives a reliable datum point for sections of the rocks above. It is one of the best marked and most regular geological associations of this region.

This ore is found at its proper level above drainage, over from two hundred and fifty to three hundred square miles in this region. The total area of the ore is of course nothing like so large as this, for the very tops of the hills, in a portion of this region, are only covered by the ore, and the area of the valleys and the slopes of the hills below the ore is much greater than that of the ore itself. It has been, however, originally deposited over all this region, but has been since carried away by the slowly acting erosive agencies which have cut out the valleys.

The best development of this ore is in the ridges between, and at the head of, the branches of Little Sandy on the west. It is in this region that Raccoon, Buffalo, and Laurel Furnaces are situated. They draw their ore from banks on the neighboring hills. Toward the Ohio river, as already noted, the ore seems to be wanting. It is first found in any quantity at the head of Alcorn Creek, and between Alcorn and Raccoon Creeks. South of this, in the drainage of Raccoon, Clay Lick, and Oldtown Creeks, this ore is at its very best. It is of uniformly good quality, and lies so near the tops of the hills that the overlying earth and shale does not soon become too thick to be cheaply removed.

At Raccoon Furnace the ore has been mined for over forty years. The Company, Raccoon and Brown banks on this property, have furnished many thousand tons of ore. It is of very

good quality, although at the Company bank it becomes quite calcareous. It varies from seven to twelve inches in thickness, and is occasionally thicker. Often scattered kidneys are found in the shales above. When this is the case, the kidneys are commonly of better quality than the block, especially if it be of unusual thickness.

At the Brown bank a thin coal is found above the ore, with the intervention of a few feet of shales. The coal is six inches thick; above it is four feet of shale, and then eight feet of sandstone, which is full of impressions of *Lepidodendra*. The usual roof of the ore is a clay shale. Mining has been carried on so long at these banks that the ore in them, which is available by stripping or benching as it is called, is becoming exhausted, and it is now necessary to drift for it.

At Buffalo Furnace, the principal banks where this ore is obtained are south of the furnace, between Clay Lick and Oldtown Creeks. Here the ore is often in two beds, with from one to three feet of shale between. The kidneys occur above the upper of these with a good deal of regularity. The lower of these two ore beds is very often quite thick and sandy, while the upper bed and the kidneys are uniformly of good quality. It is said by the miners, that where the kidneys are large and numerous, lying thickly packed together, the underlying block ore is apt to be thin; and vice versa, where the kidneys are small and scattering, the block ore is usually thick.

At a bank near the furnace, the ore shows another of the changes to a locally calcareous deposit. An analysis of this is given in No. 6 of the table of analyses of upper block ores. The change is accompanied by a considerable thickening.

Laurel Furnace is supplied with this ore from banks in all directions from it. On the north the Buck Smith, Baker, and other banks, have furnished large amounts of ore. The Buck Smith bank is now worked out. The Baker bank is still yielding a considerable amount, which is obtained by drifting, all the ore which is available by benching having been some time since exhausted. The ore now obtained is all the unaltered carbonate, of very good quality. It ranges from five to ten

inches in thickness, and rests upon a coal of about six inches thickness.

An analysis of the Baker bank ore is given in No. 2 of the table of analyses of upper block ores, siderites. There are numerous openings of this ore near the head of Oldtown and Lost Creeks, and on the Tygert Creek ridge. One of the best known of these is called Mt. Tom, and is near the head of Lost Creek. Other banks are opened on the ridge south of Oldtown Creek below the furnace.

This ore at Mt. Tom is of most excellent quality. It lies so near the top of the hill that it has been all altered to limonite, and in the process converted into the so-called "kidney block" ore, in which the blocks into which the stratum weathers, are changed to a semi-concretionary form, with the silicious and earthy impurities separated into the center.

On the Everman's Creek hills this ore is found regularly at its proper level. It was opened at a number of places in the time of the operation of old Pactolus Furnace. On the divide between Everman's and Tygert Creeks, within a short distance of Tygert Creek, this ore is opened on a hill called the Potato Knob, one of the highest of this region, and the only one in this vicinity which is high enough to hold the ore. The ore obtained from this bank is used at Iron Hills Furnace, distant therefrom about two miles. It has the same character as the Mt. Tom ore, being all limonite, of a dark red color and excellent quality. Instead, however, of being one thick bed, the ore with a total thickness of from eight to twelve inches, is split up into two or three layers, with a small thickness of shale between. An analysis of this ore, as well as of that from Mt. Tom, is given in the table of analyses of upper block ores, limonites. Between Everman's and Barrett's Creek this ore is finely shown at the Stewart bank. It also occurs at the head of Barrett's Creek, and on the divide between Barrett's and Little Sinking Creeks. It is mined considerably in this region and hauled to the railroad at Grayson for shipment. Further south, in the drainage of Big and Little Sinking Creeks, it is reported to be present, but has not been much developed.

The probability is that it will be found there wherever the ridges above the conglomerate are sufficiently high; for it is found in abundance, at its proper place on the east side of Little Sandy, some distance above these Creeks.

East of Little Sandy this ore occurs with great regularity over a large field, but is carried down by the dip of the rocks, and overlaid by numerous other ores. As a general rule it is thinner on the east of Little Sandy than it is on the west. Moreover, the slope of the hills is such that the stripping soon becomes too deep for profitable mining, and, as the higher ores are of equally good quality and often thicker, the block ore assumes a minor importance. Nevertheless, it is mined in considerable quantity at many places. In this region it is usually called the "little block" ore.

Beginning, then, at the southern part of this region, in the valley of Little Fork of Little Sandy river, near Willard, Carter county, we find the ore well developed. It has not yet been largely mined in this neighborhood, but whenever it has been sought for in its proper place, it has been found. It has been opened at quite a number of places in this region—enough to ascertain its presence. If it is present it has not been much mined below Mt. Savage Furnace, on Straight Creek. Above the furnace, however, and on the branches from the north, this ore is found quite regularly, until it is carried below the drainage by the dip of the rocks.

On Stinson Creek it is quite abundant, and of very good quality. It is mined in considerable quantity and carried to Mt. Savage Furnace. Usually it is from three to eight inches thick. The quality is shown by analysis No. 12 of the table of upper block ore analyses, limonites.

On Wilson Creek the ore is found in considerable quantity; usually thicker than on Stinson Creek. It has been mined until nearly all the limonite has been exhausted, and the unaltered blue carbonate is now only found. The quality of it is shown by analysis No. 3 of the upper block ores, siderites. The ore obtained from this region was formerly used at Star Furnace. It now goes to the Norton Iron Works at Ashland.

On the upper part of Cane Creek this ore is not much mined. Lower down, near Hunnewell Furnace, it occurs quite regularly, and at many places all that is obtainable by benching or stripping has been mined.

On Turkey Lick Creek the ore is found quite regularly; also, between Hunnewell Furnace and Little Sandy River.

On Brush Creek, a branch of Williams' Creek, on the Buena Vista property, the ore is found at a number of places, but it has not been mined to anything like the extent that it has been on the Little Sandy slope. This statement may be made a general one. Although the ore is found at a number of places on Williams' Creek and its branches, it is nowhere so valuable or so regular as on the immediate branches of Little Sandy.

On Sandsuck and Culp Creeks it is found, and has been mined in large quantities for Pennsylvania Furnace. Its quality is about the same all through this neighborhood. Its thickness is also quite regular, ranging from four to eight inches. The No. 3 coal has been opened at a large number of places, almost always holding its proper distance below, and serving as an additional evidence of the identity of the ore.

In the valley of the East Fork, below Williams' Creek, the ore has been considerably mined, as also on Indian Run and Ash Creek. In the neighborhood of old Steam Furnace there are a number of banks where it has been and still is worked. West of this and east of Little Sandy river, below the mouth of East Fork, there does not seem to be a great amount of this ore. This is probably the eastern end of the barren territory along the Ohio river; for east of this the ores extend to the banks of the river in as great abundance as found anywhere.

At Amanda Furnace, on the very bank of the Ohio river, this ore is found in unusual thickness. It measures from ten to twelve inches, and sometimes thicker. Nearly all the limonite has been exhausted, and only the blue carbonate is now obtained. This is a coarse-grained ore, somewhat silicious, and rather below the average of this bed, as is shown by No. 4 of the table of analyses of upper block ores, siderites. At this place it contains a number of fossils, a feature which is

exceptional in this ore. It is not far above the level of high water-mark in the Ohio river. East of this the ore disappears below the drainage.

There is no ore of any importance above the main block ore, for a distance of from sixty-five to eighty feet. At this level occurs an ore which has been referred to already in the description of the kidney ores. It is known by a variety of names, such as "slate ore," "lime kidney," "grey lime," &c. It is usually found about twenty feet below the ferriferous limestone. It is sometimes a regular block ore, but oftener occurs as a kidney deposit, and generally of good quality. It does not occur with the regularity of many of the other ores, but, on the other hand, it is considerably more than a local deposit. It is found quite generally in the region around Bellefont Furnace, on Hood's Creek, Chinn's branch, and around Caroline and Steam Furnaces. On the Pennsylvania Furnace lands it is found at the head of Culp Creek and other places. It occurs on Williams' Creek, Buena Vista Furnace property, and also on Straight Creek. Around Hunnewell Furnace it seems to be frequently wanting. On the head of Cane Creek, Star Furnace property, it is well developed as a block ore. It is found at a number of places on the Mt. Savage property, and is well developed around Willard, Carter county.

An analysis was made of an average sample of this ore, from the head of Cane Creek, with the following result:

Peroxide of iron	53.653
Alumina	4.324
Brown oxide of manganese	.368
Carbonate of lime	trace.
Carbonate of magnesia	.101
Phosphoric acid	.313
Sulphuric acid	.220
Silica and insoluble silicates	30.940
Combined water	10.150
Total	100.069
Metallic iron	37.551
Sulphur	.086
Phosphorus	.136

THE UPPER OR FERRIFEROUS LIMESTONE ORE.

This ore has been already described, in some detail as to quality and manner of occurrence, in the general description, and a number of analyses given.

Some discussion of the geological position and the distribution will be all that is necessary here. It rests upon the ferriferous limestone, which holds a place in the general section about four hundred feet above the base of the coal measures. Its normal distance above the main block ore is about ninety feet, although it varies somewhat.

The limestone and its equivalency have been already described in the report of Mr. Crandall. It is rarely over five feet thick, and oftener thinner, frequently disappearing altogether. The ore is usually overlaid by a heavy bed of white marl or fire-clay; and when, in the cases already referred to, the limestone is absent and the ore extends beyond the area of the limestone at the same level, the fire-clay is almost always present above the ore, and often serves to identify it.

Beginning at the Ohio river, below Amanda, the ore is found in the hills along the river back of, and to some distance above, Ashland, when it becomes irregular, and is only occasionally found, or when found the limestone is wanting. Mr. Crandall found the ore as far up the river as Key's Creek, but it is not in any great quantity, as it seems to occur only in small detached beds, in which the ore is quite thin and only of medium quality. Although the limestone is wanting, the characteristic white clays are still found above the ore.

Back of Amanda the ore and limestone occur quite regularly, underlying a large part of the so-called "Flat Woods," in the neighborhood of Bellefont and toward Caroline Furnace.

Back of Bellefont Furnace, in the valley of Hood's Creek, and towards East Fork, the ore is found quite regularly; but east of Hood's Creek the limestone thins out and disappears, and we then have only occasional patches of the ore with associate white clay.

Large quantities of this ore have been mined for Bellefont Furnace, in the valley of Hood's Creek, but the stripping now

necessary in order to reach the ore has become so deep, that the kidney ores are more profitable to mine; so that the proportion of limestone ore now received at the furnace is not so great as formerly. At Amanda Furnace the ore is overlaid by two or three beds of fire-clay of different quality, some ten to fifteen feet thickness in all. This clay is largely used for the manufacture of fire-brick at the Bellefont works, and for pottery in Cincinnati.

As it is quite valuable it pays for the stripping, and thus the ore can be profitably mined, even when the stripping is carried to the unusual depth of twenty to twenty-five feet. At one of the benches back of Amanda the following section was shown:

	Feet.	Inches.
Soil	4	.....
Clay shale	6	.....
Coal	.....	4
No. 2 fire-clay	3	.....
Pottery clay	4	.....
No 1 fire-clay	3	.....
Limestone ore	.....	8
Top of ferriferous limestone.		

Around Caroline and old Steam Furnaces, and in the hills to the south towards East Fork, on Indian and Ash Creeks, this ore occurs very regularly, and usually in quite heavy beds. The ore has been mined in this region for nearly fifty years, however, so that all, or nearly all that is available by stripping, has been removed. There is an abundant supply of the ore yet remaining, but it will have to be won by drifting, and it is nearly all the blue unaltered carbonate. It is usually sufficiently thick to pay for drifting, ranging from one to three feet, and occasionally higher, at some of the banks. This was the ore relied upon for the main supply at these furnaces when they were in operation; but they went out of blast upon the exhaustion of the limonite, not being able, as they supposed, to successfully use in charcoal furnaces the blue carbonate ore for the production of a coarse-grained foundry iron.

Across East Fork, on the Pennsylvania Furnace lands, this ore is generally found at its proper level. As at Bellefont however, the proportion of limestone ore obtained in the past was greater than at present, for the supply available by stripping has been nearly exhausted, and as yet it has not been much drifted for. The principal deposits are on the ridge between East Fork and Little Sandy, but best developed on the Little Sandy side. This holds good along the whole length of this ridge. South of this furnace, at the head of Culp and Sandsuck Creeks, on Pea Ridge, as it is called, the ore is well developed and has been extensively mined. It is now mined by stripping twenty to twenty-five feet of overlying fire-clay, shale, and sandstone. Both the ore and the limestone are mined, the limestone being used for flux at the furnace.

The ore here is overlaid by a series of fire-clays very similar to those at Amanda. As yet they have not been put to any profitable use. The time will doubtless come when they will be made a source of profit.

The limestone here varies from two to five feet in thickness, and the ore from four inches to twenty, with an average, so far as seen, of about eight. South of Pea Ridge, the limestone ore is somewhat irregular and uncertain. It is found at a large number of places along the ridge, between Williams' and Cane Creeks, but is not now mined in any great quantity.

It occurs at the head of Brush and Straight Creeks, on the Buena Vista Furnace property, and in small patches, well down toward Williams' Creek, but the limestone is generally wanting and the ore is of minor importance. Around Hunnewell Furnace it is well developed, and has been considerably mined, more in the past than at present, as the supply of limonite from this bed is nearly exhausted, and the furnace does not use the carbonate. There are large quantities of the carbonate ore in this region, which could be profitably obtained by drifting if there were any demand for it.

West of Cane Creek the ore occurs without the limestone, and is known as the slate ore. It is of good quality, as shown by analysis No. 8 of the table of analyses of limestone ores,

limonites. Toward the head of Cane Creek, and on Wilson Creek, the limestone ore is rarely found. On Williams' Creek, above Rush Station, it is found sometimes as a dense calcareous ore, but with no underlying limestone. The ore consists of a light-grey calcareous matrix inclosing small sub-crystalline specks of a darker color.

An analysis of an average sample, taken from the Star Furnace stock pile, is as follows:

Peroxide of iron	21.433
Carbonate of iron	19.802
Alumina	1.193
Carbonate of lime	30.205
Carbonate of magnesia	trace.
Carbonate of manganese	.240
Phosphoric acid	.257
Sulphuric acid	.157
Silica and insoluble silicates	23.080
Combined water and loss	3.633
Total	100.000
Metallic iron	23.109
Sulphur	.062
Phosphorus	.112

At other places on the Star Furnace property the ore loses this calcareous nature and occurs as a thin block ore, when it is known as the "slate ore" or "little block." This is another instance of the careless and incorrect manner in which names are applied to the ores all through this region. On Wilson and Stinson Creeks the ore seems to be generally wanting or if it be present, it has been very little worked. Further south in the Mt. Savage Furnace region, on the branches of Straight Creek, the ore and limestone are found, but they occur irregularly and in patches. The limestone is usually thin, and is more uncertain than the ore. The so-called "grey limestone ore," or "limestone kidney ore," which has been already described as occurring from fifteen to twenty-five feet below the limestone, is here more regular and in greater quantity than the limestone ore itself. Still further southeast, in the region around Reedville Station and Willard, the ore has a fine development, and occurs with as great regularity and

thickness as anywhere in these counties. At the Reed and Graham banks, and many other localities, it is extensively mined. East of Willard the ore is carried below the drainage by the dip of the rocks, while to the south, up Little Fork and Dry Fork, the change of dip which here occurs, carries it rapidly up and gives a large outcrop area above the drainage. This is one of the most promising undeveloped localities in this region. The ridge between Little Fork and Little Sandy is the western boundary of this ore.

The Graham bank is situated upon a spur of this ridge. The ore here shows from one to three feet thickness, and sometimes is even thicker, all of most excellent quality. An analysis of ore from this bank is given in the table of limestone ore analyses, limonites, No. 10.

The ore is found in very promising outcrops at the head of Little Fork of Little Sandy, and on the head of Cherokee Fork of Blain Creek. I am informed by Mr. Crandall that it also is present in considerable quantity, and quite regularly, on nearly all of the upper branches of Blain Creek, in Lawrence county. At none of these places has it been mined, but it is found scattered over the surface in considerable quantity, and can be traced to its place above the limestone, which is usually present, thus increasing the probability that the ore will be found in abundance when mining operations are undertaken.

From the above somewhat detailed description of the distribution of the limestone ore in these counties it is seen, that while nearly always of remarkable good quality, it is somewhat uncertain in its occurrence and irregular in its thickness, and for this reason is of less value, taking it through the whole of the three counties, than some of the other ores. Where it does occur in any quantity there is no ore in this region of so much value,

In portions of this region it is now, and always will be, the ore of most value, for it will yield a regular supply of ore by drifting. It is probable, also, that in many other places where the available supply of this ore is considered to be exhausted,

because the stripping is now too deep for profitable mining by benching, it will be found that it can be profitably mined by drifting, systematically carried on, although now supposed to be too thin to pay for working in that way.

THE KIDNEY ORES.

We come now to the examination of this interesting class of ores, the occurrence of which, in any workable quantity and great regularity, properly begins above the horizon of the limestone ore. What the circumstances were, which, from the time of the deposition of the ferriferous limestone, induced the deposition of all the ore, or so large a proportion of it as to leave the remainder hardly worth mentioning, as nodular segregations instead of the strata which had formed the larger portion before that time, we are unable to tell. Certain it is that there has been such a change, and that we no more find layers of block ore, extending regularly through the hills; but in their place, at certain well-defined levels, masses of nodular ore, often in quantity sufficient to form unusually heavy beds, were all of it condensed into a connected stratum. These nodules, unlike the block ores, preserve a uniform character, even when the size is greatly increased; or, speaking more accurately, the quality does not seem to be affected by the size of the deposit.

The first of these deposits is found about fifty feet above the limestone ore, ranging, however, from forty to sixty. It generally consists of two layers or beds of nodules, lying in shale, and separated from two to eight feet. Often the kidneys are scattered through the whole space, and do not separate into layers or "runs," as they are called by the miners. There is a great confusion in the names applied to this ore. It is called by different names at different places, and then again separate names are given to the two members of it. It is called the yellow kidney ore pretty generally through the southern part of this region, and the black kidney or the "black vein" nearer the Ohio river; while at some places the name yellow kidney is applied to the lower member and "black vein" to

the upper. In referring to it here, the name yellow kidney or kidney ore, No. 1, will be applied to both members, considering them as one ore, as they essentially are.

The nodules or kidneys are, before alteration to limonite, usually of a dark brown or blueish color, and quite fine-grained, though occasionally they show a coarse structure, somewhat oölitic and sandy. In alteration from the carbonate to limonite the ore oxidizes in concentric layers, and between each of these layers there is a thin coating of bright yellow ochre, which is the most conspicuous feature of the ore when a specimen is broken open. From this the name yellow kidney has been applied. All of the deposits of nodular or kidney ore show this feature, to a greater or less degree, so that the name yellow kidney is not at all distinctive, but might be equally well applied to all. It is only used in this instance because it is more commonly applied than any other.

As already stated, this ore, although not a continuous stratum, is still one of the most reliable, regular, and persistent deposits of this whole region. It shows a much greater regularity than the limestone ore below it. It occurs from fifteen to twenty-five feet below the coal No. 7, the well-known Coalton coal, and often serves, by this occurrence, to identify the coal at widely separated localities.

It is found, with exceedingly slight variations, over a large area, from two hundred to two hundred and seventy-five square miles in all, above drainage; beginning on the west, in the spurs of the divide between East Fork and Little Sandy, towards Little Sandy, and extending to the eastward until it is carried below the drainage or reaches the boundary of the State. It extends to the Ohio river in almost as great a development as it shows in any portion of this region. Along the river it is first found in the river hills back of and below Amanda. It is here held only by the highest hills, close to the river, and is not found in the so-called "Flat Woods," a range of low, flat hills extending back about two or three miles. It occurs in the hills back of the river above Ashland, and in the valley of Key's and Catlett's Creeks, gradu-

ally descending with the dip of the rocks until it is nearly at the level of high water in the Ohio river, below Catlettsburg. In the immediate neighborhood of Catlettsburg the ore seems to be absent, a coarse, heavy sandstone occurring in its place. Back of the Ohio river from Catlettsburg, the line along which the ore passes below the drainage runs in a southwest course, crossing Shope's Creek and Marsh Run near the head, and East Fork near the mouth of Old Trace Creek. From here it crosses Rush Creek, about two miles above its mouth, Williams' Creek, near its head, Straight Creek, between three and four miles from its head, and Lost Fork, about two miles from its mouth. It then turns south and passes out of Carter county near the mouth of Bell's Trace Creek.

The kidney ores and some of the local limestone ores, which are found high up in the series in the middle coal measures, are all that are found in the neighborhood of Clinton Furnace, and were the ores used at that furnace when in operation. The yellow kidney ore is well developed in this region, lying in large nodules and very close together. At this place, in the kidneys, large numbers of impressions of ferns and other plants were found. West of Clinton Furnace, in the valley of Hood's Run and East Fork, on the Bellefont Furnace property, this ore is very abundant and is mined in large quantities. By far the greater proportion of all the ore used at Bellefont Furnace is kidney ore. This ore is found over nearly the whole of this property, with the exception of that portion of it which lies in the "Flat Woods," already referred to.

Around Caroline and Steam Furnaces it occurs in the tops of the highest hills, and the area covered by it, in proportion to the whole, is small. South and east, however, towards East Fork, it is found in great abundance.

South of East Fork, on the Pennsylvania Furnace lands, it is present in large quantity and is extensively mined. To the west it reaches well toward Little Sandy, on the Culp and Sandsuck Creek hills, but is found in largest quantity at the head of these creeks, and on the East Fork and Brush Creek

slopes. Like Bellefont, Pennsylvania Furnace uses more of the kidney ores than any other class.

On the Hunnewell property this kidney ore is found along the main divide between Williams' Creek and Little Sandy, and on some of the hills between Cane Creek and Little Sandy. This furnace uses probably a greater variety of ores than any other charcoal furnace of this region, having the block, limestone, and kidney ores on its own lands, and receiving large quantities of both upper and lower block ore by railroad; but of that now mined on its own property probably two thirds or more is kidney ore.

This kidney ore is found on all portions of the Buena Vista Furnace property, and has been extensively mined. It extends to the east beyond Williams' Creek and East Fork, to some distance beyond Cannonsburg. On East Fork, above Cannonsburg, the ore goes under the drainage at about the mouth of Old Trace Creek.

The valley of Williams' Creek shows the most extensive workings of the kidney ores of any portion of this region. On the lands of the Buena Vista and Star Furnaces, and the Ashland Coal Company, they are mined in large quantities, and very little ore except of this kind is obtained. There are from three to five beds of kidney ore in this region, and the hills are terraced, bench above bench, for miles around the contours by the diggings for these ores. Probably nine tenths of all the ore received at Star Furnace, Coalton, and Buena Vista, is of this class.

The yellow kidney ore passes below the drainage on Rush Creek, about two miles above its mouth, and is not found on Garner Creek or Bolt's Fork; but on Garner Creek some of the higher kidney ores occur. It is found regularly on Williams' Creek nearly to its head, and on the hills toward Wilson, Stinson, and Straight Creeks. On Wilson and Stinson Creeks it has not been much mined, except toward their heads. Toward Little Sandy, on the ridge between these creeks, the dip soon brings the lower rocks to the top of the ridge, and the ore is no more found. Between Stinson and

Straight Creeks it has been much more extensively mined. It is found in the main ridge from the head of Gum branch of Straight Creek, eastward, for about four miles, when it goes under the drainage on Straight Creek. Large amounts of it are obtained in this region for Mt. Savage Furnace. It is also mined on Davy Run. It is found on Lost Fork and Dry Fork quite regularly, but has not been as yet extensively mined.

THE RED KIDNEY ORE.

As will be seen from a number of sections accompanying this report and that of Mr. Crandall, there is a second bed of kidney ore usually occurring about fifty feet above the first, or yellow kidney, and thirty feet above the No. 7 coal. This will be here called the "red kidney ore." This name is not applied all through this region, but it is probably used more than any other. Often it is called the little yellow kidney ore, and at some places where the first bed of kidney ore is called the "black vein," the name "yellow kidney" is given to this. It is, however, easy of identification, as a separate bed, from its position above the No. 7 coal, and in the localities where that coal is most largely mined it is usually known as the red kidney. In character it is often very similar to the yellow kidney, but the ochreous coating which covers the layers into which it weathers is usually of a darker color, and often quite red. From this feature it derives its name of red kidney.

When weathering to a dark color, it is usually found to be calcareous. This ore shows, for the first time, a tendency which is more common in the beds above, to grow very calcareous at places, and change finally to a bed of cherty limestone nodules. This tendency has not been observed in the yellow kidney ore. The individual nodules of this bed are next in size to those of the yellow kidney ore; but they show a decrease, which continues and is more marked in the beds above, showing a regular diminution in size from the yellow kidney upward. Where there is the greatest number of these beds, the nodules of the upper ones, which are not found at

many other places, are of very small size, rarely weighing more than a few pounds.

The red kidney ore ranks in value next to the yellow. It is almost as regular in its occurrence, and the area over which it is found is very nearly the same, or, if anything, a little larger; for in places the western boundary is the same for both ores, being determined by a topographical feature–the main ridge between East Fork and Little Sandy–while it extends some distance further east.

The fields of the two ores are so nearly identical that the area of this ore will not be given in detail, for the description of the yellow kidney ore will answer for both, with the following points of difference: the red kidney ore does not usually extend out to the westward on the spurs of the divide between East Fork and Little Sandy, but is confined to the main ridge. It is not found, except in a very few of the highest points, in the neighborhood of old Steam and Caroline Furnaces, nor at Amanda, and is first known near the Ohio river, in the hills back of Ashland. It extends to the Big Sandy river at Catlettsburg, and along that river for some distance, being found above the drainage some distance beyond where the yellow kidney disappears, as the dip is here very gentle. It is found on the Big Sandy river nearly as far up as the mouth of White's Creek. To the south it is found on Garner Creek, and on East Fork, some distance above where the yellow kidney disappears, finally going under between the mouth of Garner Creek, and Bolt's Fork. It is found on the Mt. Savage Furnace property in considerable quantities. Around Willard it has been seen at many places, but is not as yet mined to any extent.

OTHER KIDNEY ORES.

Above the red kidney ore, at a distance ranging from ten to twenty-five feet, is another bed of ore of this class, which is found at many localities in this region, but by no means so generally as the beds just described. It is at its best on the Buena Vista, Star, Hunnewell, and Mt. Savage Furnace properties.

It is known as the black kidney at Star Furnace, but at other localities the more generally applied name is the bastard limestone ore, or, as the miners call it, the bastard lime kidney. This name is given from the usual association of the ore with, and occasional replacement by, silicious limestone nodules. Sometimes the limestone occurs as a connected stratum, and the ore overlies it as a limestone ore, but this is rare. The size of the nodules of ore is usually small, and the quantity not sufficiently great to pay for deep benching; yet it has been, nevertheless, largely mined at a number of places in this region, notably in the Williams' Creek valley, which is the only region where it is of any importance.

From twenty-five to forty feet above this last described ore occurs another, which is known as the "little yellow kidney" more generally than by another name. This has its best dedevelopment in the Williams' Creek valley, but is known at other places, as for instance, on Gum branch of Straight Creek, Mt. Savage Furnace property.

South and east of this, however, where the Mahoning sandstone is present as a heavy conglomeratic rock, this ore is wanting, as it properly occurs about the level of this sandstone. In the region where this ore occurs the sandstone seems to be replaced by a series of shales, which carry the ore.

This ore is somewhat more regular in its mode of occurrence and its quality, than that last described. The size of the nodules is usually small, rarely exceeding a few pounds in weight, but the quality is uniformly good; and it happens that in a large part of the region where it is found it occurs so near the tops of the hills that the covering of shale and earth above it is very light, and it can be mined over a large area by benching. Large quantities of it are thus obtained at Buena Vista and Star Furnaces, and at Coalton for the Ashland Furnace.

This properly closes the list of the kidney ores, although there is another bed still higher, reported at a few localities, which is called the "top hill kidney" or the "little red kidney," but it has not been identified as a separate bed by any member

of the Survey. This is also the last and highest of the ores of the lower coal measures, and the last ore of anything more than local range or value. This as already stated, occurs very near the place of the Mahoning sandstone. Above it the middle or so-called barren coal measures, prove to be barren of ore as well as coal. There are, however, in these measures, a number of limestones which are, occasionally, accompanied by ores. These are at places of very good quality, and resemble the regular limestone ore, but usually they are excessively calcareous and quite poor in iron. In addition to the inferior quality, they are, as a rule, irregular in their occurrence, so that no reliance can be placed upon them. Sometimes they are of unusual thickness, so that they have been drifted for, but these "pockets" are usually not extensive. The Oakland and Sandy Furnaces, which were built relying upon these ores for their main supply, were both compelled to suspend operations after a short time, as they could not profitably work them alone. They are often quite fossiliferous, and then seem to be little more than ferruginous limestones. Ores of this class are found, and have been considerably mined, on some of the highest hills south of Straight Creek, on Buena Vista Furnace property; also, on White's, Chadwick's, and Peterman's Creeks, whence the ore went to Oakland Furnace.

To the south but one of these is usually found. It lies above a fossiliferous limestone eighty feet above the Mahoning sandstone, and is called the Rough and Ready ore. It is found on Straight Creek (Mt. Savage), Lost Creek, and at the head of Dry Fork, above Willard, Carter county. On Bolt's Fork it is better developed than at any other locality. It is here quite a reliable bed, and is said to range from eight inches to two feet in thickness. All the old workings have fallen in, so that no opportunity was afforded members of the Survey to ascertain the thickness, by measurement, for themselves.

It was to use this ore that the Sandy Furnace was established. The quantity of ore proved ample, but the quality was such the furnace never was able to produce a first-class foundry iron. The ore was so calcareous that it more than

fluxed itself, producing a thin fluid slag, which, by its continually running off, cooled the furnace and resulted in the production of a hard, brittle, white iron. The furnace, after about three years unsuccessful working, went out of blast, and has never since been started. Were there a cheap and ready means of transportation this ore could be very successfully used for a mixture, in furnaces where the other ores used were silicious or argillaceous, and it would be of considerable value, especially to furnaces using stone-coal.

With this closes the list of the ore beds of Greenup, Boyd and Carter counties. It is the highest and last ore of anv importance in this region.

It is believed that in the foregoing pages all the ores which occur in this region in anything more than local extent, and even some of them, have been described. There have been found at a few places ores which have not been described, but they seemed to be of such limited range that they were not considered of sufficient importance to receive a special description, or a place in the general section. It may be that future developments will show these to be more extensive than now supposed, and thus add to the number of ores of the general section. The region, however, taken as a whole, has been pretty thoroughly prospected, and it is believed that the list is nearly complete.

METHODS OF MINING.

IV.

The method of mining in general use through this region is, as already stated, by stripping or benching. This, while the most economical for a time, is unavailable to any great depth, and by it only a very small per centage of the ore present in a given area is available, for when the overlying material reaches a thickness of from ten to fifteen feet, varying of course with the thickness of the ore bed, the ore will no longer pay for its removal. The slope of the hills is generally such that, with rare exceptions, such as occur where the ore lies near the top of a hill and can all be removed, this depth of stripping is reached when the width of the bench or terrace is from thirty to forty feet. A strip of ore then, in width from thirty to forty feet, and in length equal to the contour of the hill at that level, is all that is usually attainable by this method of mining.

It is unfortunate that we have not a detailed topographical map from which we could measure, with accuracy, the proportion which this bears to the whole amount of ore present in the hill; but in the lack of this nothing but an estimate can be given, and this estimate must of course be only the rudest sort of an approximation. It is believed that the amount which can be mined in this way will not exceed five to ten per cent. of the whole, if it even reaches the lower figure. The necessity then, especially at some of the older furnaces, where the ore which can be reached by benching is becoming exhausted, for a better method of mining, is becoming apparent. That this must be found in carefully planned, well-conducted, underground work, there is no doubt. Mining by drifts has been carried on at many places in this region, where the ores show an unusual thickness, but it has all been done in a hap-hazard way, the miners being left to conduct their drifts as they pleased, without any supervision.

No systematic underground mining for iron ore, under the direction of the companies owning the land, through competent mining superintendents, has ever been carried on in this region. Such operations would undoubtedly be profitable at many localities in these counties. There are two serious obstacles, however, to underground work: one is the thinness of the ore beds; the other the character of the roof, which is usually a soft, crumbling shale, or, as sometimes in the case of the limestone ore, a fire-clay.

What is the limit of thickness below which an ore cannot be profitably mined underground will have to be proved by trial, but there seems to be little doubt, that with properly conducted operations, it will be considerably less than now supposed. As a rule at present, no ore is drifted for which is less than from one foot to eighteen inches in thickness, although at some places an ore averaging not more than from six to eight inches is mined in that way, at a cost for mining of from three to four dollars per ton.

As yet the method of longwall mining, which is so commonly employed abroad in working thin beds of ore, has never been tried in this region. Were the same amount of skill devoted to mining the ores of this region as is expended in coal mining, it would be found that they could be mined much more cheaply than commonly supposed; and thus large quantities of ore which are now considered of no value, being thought too thin to work, would be rendered available sources of wealth.

The limestone and block ores have been already mined by drifting at a number of places, and in future will be much more extensively worked in this way. Whether the kidney ores will ever pay for underground exploitation is an open question, as the experiment, so far as the writer knows, has never been tried.

In cases where the kidneys are of large size, and concentrated in a few feet of shale, it seems not improbable that it might be successfully done, but in the majority of cases the amount of ore would prove so small, in proportion to the shale necessary to be moved to reach it, that it would not pay. The

amount of ore in one of the kidney beds, in a given area, has never been accurately determined. No calculation can be made of it with any degree of accuracy. The only way to determine it is to strip a measured area of considerable size and weigh the ore found.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

THE IRON MANUFACTURE

OF THE KENTUCKY DIVISION OF THE

HANGING ROCK IRON REGION,

BY P. N. MOORE.

SOME NOTES UPON THE IRON MANUFACTURE IN THE KENTUCKY DIVISION OF THE HANGING ROCK IRON DISTRICT.

The Hanging Rock Iron District takes its name from a peculiarly shaped rock exposure upon the Ohio river, near which is now the village of the same name. Some of the early furnaces were located near and had here their landing place. The name Hanging Rock pig iron was applied to the product of these furnaces, and as the number of furnaces increased the name was still retained, until now it is applied to all the iron produced in a number of adjoining counties, in both Ohio and Kentucky. The region now embraces in Ohio the whole or parts of Scioto, Lawrence, Gallia, Jackson, Vinton, and Hocking counties, and in Kentucky, the counties of Greenup, Boyd, and Carter, and it will, without doubt, eventually extend still further to the southward.

In this region the native ores of the coal measures are those in most general use. They are used exclusively by the charcoal, and very largely by the stone-coal, furnaces.

The Hanging Rock iron has an excellent reputation throughout the West. It is used for a variety of purposes; but perhaps more generally for foundry purposes than any other. For general foundry use, combining strength with fluidity and small shrinkage in cooling, it is probably unsurpassed in this country, if anywhere. It can also be used with a considerable proportion of scrap without injury to the resulting castings.

Certain brands of the cold blast charcoal iron have a national reputation for the manufacture of car-wheels, for which purpose they are unsurpassed.

The iron from the stone-coal furnaces of this region is used for both foundry and mill purposes, but most largely in the mills, for conversion into wrought iron. The fuel in use at a majority of the furnaces is charcoal. It was upon charcoal iron

that the reputation of this region was established. It was not until within the past ten years that the use of stone-coal for the manufacture of iron was introduced. It has grown rapidly since that time, and is destined to become the prevailing industry; but as yet the charcoal largely outnumber the stone-coal furnaces. There are in this region sixty-one furnaces, either in active operation or in a condition to be put in operation in a short time. Of the whole number, forty-four are charcoal and seventeen stone-coal. Of these, thirteen are situated in Kentucky, of which eleven are charcoal and two stone-coal furnaces.

The following is a list of these furnaces:

CHARCOAL FURNACES.

Name.	When built.	County.	Owners.
Bellefont . .	1826	Boyd . .	Means, Russell & Means.
Boone . . .	1856	Greenup .	Nathaniel Sands & Co.
Buena Vista .	1847	Boyd . .	Means & Co.
Buffalo . . .	1851	Greenup	Culbertson, Earheart & Co.
Hunnewell .	1845	Greenup .	Eastern Kentucky Railway Company.
Iron Hills . .	1873	Carter .	Iron Hills Railway, Mining, and Manufacturing Company.
Laurel . .	1849	Greenup	Robert Scott & Co.
Kenton . . .	. . . .	Greenup .	Kenton Furnace Railway and Manufacturing Company.
Mt. Savage .	1848	Carter . .	Lexington and Carter County Mining Company.
Pennsylvania.	1845	Greenup .	Eastern Kentucky Railway Company.
Raccoon . .	1833	Greenup	Raccoon Mining and Manufacturing Company.

STONE-COAL FURNACES.

Ashland. . .	1869	Boyd . .	Lexington and Big Sandy Railroad Company, East'n Div.
Norton . . .	1873	Boyd .	Norton Iron Works Company.

In addition to these, there were quite a number of furnaces formerly in operation in this region, which have been discontinued from various causes, usually either poor original location, exhaustion of timber supply for charcoal, or unsuccessful management. They were all charcoal furnaces, although one of them, Star Furnace, used stone-coal during the last few years it was in operation.

The following is a list of these:

Name.	When built.	County.	Builders.
Argillite	1822	Greenup . . .	Trimble Brothers & Deering.
Pactolus . .	1822	Carter	McMurtril & Ward.
Steam	1824	Greenup . . .	Shreve Brothers.
Enterprise . . .	1826	Greenup	Deering, McCoy, Clingman & Co.
Amanda	1829	Greenup	Pogue Brothers, Culvert & McDowell.
Clinton	1830	Boyd	Pogue Brothers.
Globe.	1830	Greenup . . .	Darlington & McGee.
Hopewell .	1833	Greenup	Wm. Ward.
Caroline . . .	1833	Greenup	Henry Blake & Co.
Oakland . . .	1834	Boyd	Kouns Brothers.
New Hampshire . . .	1846	Greenup . . .	
Star	1848	Carter	
Sandy	1853	Boyd	

The most of the above given dates and names of builders were kindly furnished the Survey for publication by Col. J. Bell, of Ashland. Mr. J. Russell, of Bellefont Furnace, also furnished information which aided the completion of the list.

From the above list it will be seen that the first furnaces of this region were Argillite and Pactolus, built in 1822. It has been stated by Mr. Andrews, in the Ohio Geological Report for 1870, page 217, that the first furnace in the Hanging Rock region was the Union Furnace, built in 1826, by Sparks, Means & Fair. From the above list it will be seen that three Kentucky furnaces in this region were built before Union Furnace, viz: Argillite, Pactolus, and Steam, while two others, Bellefont and Enterprise, were built the same year. To Kentucky, then, properly belongs the credit of having first started the manufacture of iron in this now important region. Although not relating immediately to this region, the fact is worth stating at this place, that in Kentucky was built the first iron furnace in the West, and one of the earliest in the country. This was called Slate Furnace, and was situated in Bath county, upon Slate Creek, a branch of Licking river. It was built as early as 1791, and went out of blast after about thirty years operation. Of the Hanging Rock furnaces given in the above list, Argillite, Hopewell, Pactolus, Enterprise, and Globe were built adjacent to water-power, which was used for driving

the blowing machinery. Argillite, Hopewell, and Pactolus were upon Little Sandy river, Globe and Enterprise upon Tygert Creek. The water-power was not sufficient at all times of the year, and in one case at least a furnace was chilled by the failure of the water requisite to drive her blast engines. The result was that they were all soon abandoned, and others erected using steam-power. The first furnaces were of small size compared with those of the present time, and their production was correspondingly small. Steam Furnace, for instance, was first erected twenty-eight feet high by eight and a half feet bosh, and is said to have produced only three tons of iron per day. It is reported that Argillite Furnace was still smaller, being only twenty-five feet high by six feet bosh, and made only two tons per day. The site for this furnace was excavated out of the shale near the end of the dam, and it was so low that in time of floods the water could only be kept from the furnace by means of coffer-dams.

The present charcoal furnaces are much larger, and produce from ten to sixteen and even twenty tons per day. They are nearly all built after the old model, with a massive stone stack in the form of a truncated pyramid. With one exception, Iron Hills Furnace, the model of all the charcoal furnaces, is the same. They are built against a hillside, at the base of which the rock is excavated to give room to place the stack. The ore and charcoal are hauled in wagons to the stock bank at the level of the furnace throat, and thus the necessity for an elevator is obviated. The boilers are placed over the furnace throat, and the hot blast ovens at the end of the boilers, so that the waste gases are utilized effectually. The engine in common use is horizontal, with one steam cylinder working two blast cylinders, which are geared in such a manner that when the piston of one is at its least velocity the other is at its greatest, and thus a comparatively constant pressure of blast is obtained without the use of a reservoir to regulate it. The engines are usually geared to make one stroke of each blast cylinder to two of the steam cylinder, which is equivalent to stroke for stroke, as there are two of the blast

cylinders. The furnaces are usually worked with open hearth, and most of them use but one tuyere, entering at the side. The hearths are generally constructed of sandstone, of which there is an abundance of good quality on most of the furnace estates. Formerly the inwall or lining was also generally of sandstone, but of late years the use of fire-brick for that purpose has become more common.

Most of the furnaces are without either pressure gauge or pyrometer, so that the pressure and temperature of the blast are not known with any accuracy, the general rule being to heat the blast as high as possible with the ovens at command, and to keep the pressure as great as the steam will allow, varying it, of course, according to the necessities of the furnace working. It is probable that the general pressure of blast does not vary much from two and a half to three pounds.

The following table gives the principal dimensions and other details of the charcoal furnaces in this portion of Kentucky:

CHARCOAL FURNACES IN THE KENTUCKY DIVISION OF THE HANGING ROCK IRON DISTRICT.

	Bellefont	Boone.	Buena Vista.	Buffalo.	Hunnewell.	Iron Hills.	Kenton.	Laurel.	Mount Savage.	Pennsylvania.	Raccoon.
Height	34′	44′ 7″	40′	36′ 6″	47′	49′	37′	39′	39′	36′	35′
Diameter of bosh	10′ 6″	10′ 6″	10′	10′ 6″	12′	12′ 6″	10′ 6″	10′ 6″	11′	10′ 3″	10′ 6″
Batter or slope of bosh	53°	53°	53°	55°	53°	53°	50°	55°	53°	50°	53°
Diameter of throat	3′ 8″	2′ 4″	3′ 4″	3′	3′ 6″	7′ 6″	2′ 8″	3′	3′	2′ 9″	2′ 10″
Height of hearth	6′	6′	6′	6′	6′	6′ 6″	6′ 2″	6′	6′	6′	6′
Diameter at top	3′ 8″	3′ 8″	3′ 7″	3′ 10″	4′ 1″	4′ 6″	3′ 8″	3′ 9″	3′ 8″	3′ 6″	3′ 4″
Diameter at bottom	2′ 2″	3′ 2″	3′ 1″	3′ 5″	2′ 8″	3′ 6″	3′ 4″	3′	2′ 6″	2′ 7″	2′ 10″
Number of tuyeres	1	1	1	2	1	3	1	1	1	1	1
Diameter of tuyeres	4″	4″	4″	3′ 2″	4¾″	3′ 2″	4″	4″	4″	4″	4″
Height of tuyere above bottom of hearth	2′ 3″	2′ 10″	2′ 8″	2′ 6″	2′ 2″	2′ 9″	2′ 1″	3′	2′ 10″	2′ 8″	2′ 8″
Number of boilers	2	2	2	2	3	3	2	3	3	2	2
Diameter of boilers	2′ 8″	3′	3′	2′ 9″	3′	. . . . .	3′	2′ 9″	. . . .	3′ 4″	. . . .
Length of boilers	46′	48′	52′	32′	50′	. . . . .	48′	37′	38′	50′	. . . .
Number of blast cylinders	2	2	2	2	2	1	2	2	2	2	2
Diameter of blast cylinders	4′	4′	3′ 1″	3′ 4″	4′	5′ 6″	2′ 6″	3′ 3″	3′ 1″	3′ 8″	4′
Stroke of blast cylinders	5′ 6″	6′	5′	6′	5′	4′	5′ 6″	4′	5′	4′ 6″	4′
Diameter of steam cylinder	1′ 6″	1′ 6″	1′ 3″	1′ 3″	1′ 6″	2′	1′ 3″	1′ 3″	1′ 3″	1′ 4″	1′ 3″
Stroke of steam cylinder	5′ 6″	6′ 10″	5′	6′	6′ 6″	4′	5′ 8″	4′	5′	5′ 6″	5′
Kind of hot blast ovens	Davis.	None, cold blast	Davis.	Davis.	Hoop.	Hoop.	Hoop.	Davis.	Davis.	Hoop.	Hoop.
Usual pressure of blast	3 lbs.	.	3½ to 4 lbs.	. .	3 lbs.	2½ to 3½ lbs.	. . . .	. . . .	. .	. . . .	. . . .

It will be seen from the above table that, with the exception of two furnaces, Hunnewell and Iron Hills, there is no very great difference in the size or general details of construction. Hunnewell Furnace is also built on the same model, but is larger than usual.

Iron Hills Furnace is, however, constructed on an altogether different and more modern pattern, and one sufficiently novel for this region to deserve a special description.

The furnace has an iron shell stack resting upon iron pillars, fire-brick hearth and lining or inwall, closed top with bell and hopper charging apparatus, and a gas flue for carrying the waste gases to the boilers, which are situated on a bank about twenty-five feet below the top of the furnace. The boilers are situated upon the same level as the stock bank, and an inclined plane elevator is used to hoist the charges to the furnace throat from this level. The hot blast, which is of the Hoop patent, is situated at the end of the boilers. The furnace was built to run upon the Lambert ore, which has been already described. It started at a very inauspicious time for a new enterprise of the kind, the winter of 1873–'74, and was compelled, through financial troubles, to cease operation in the following spring, after having made only nine hundred and sixty-two tons of iron. Since that time it has been idle, but it is to be hoped that it will not long remain so.

It has been freely charged that the lack of success of the furnace was due to the novelties introduced in its construction: notably the substitution of gas flues for taking the gases down to the boilers instead of placing the boilers over the throat of the furnace, in accordance with the time-honored custom. There is certainly no reason why this plan, which has been successful at other places, and which is being introduced in the latest and most improved charcoal furnaces in other regions, should not be successful here also. If it has not been, it may possibly be due to defective construction, improper size of flues, insufficient draft, or some other similar cause; but there certainly is no reason why the gases from a charcoal furnace cannot be taken down through flues and then consumed

in heating boilers and hot blast as well as those from a coke furnace. There is no material difference in the composition of the gases.

In working the furnace it was found that the hot blast apparatus never was heated sufficiently to give a temperature to the blast of more than three hundred degrees to four hundred degrees, and it usually was about two hundred degrees, hardly warm enough to be called hot blast. It is not unlikely that the situation of the hot blast apparatus at the end of the boilers is too far from the place of combustion, which principally takes place where the air is first admitted under the boilers at the end nearest the furnace and farthest from the hot blast stove, so that in reality it receives little more than the waste heat from the boilers, all the combustible portion of the gases being consumed before reaching it. It is probable that if the hot blast apparatus were placed nearer the furnace, with a separate flue to conduct a portion of the gases directly to it, there to be consumed, it would be found as effective as desired, and, with the furnace working properly, there would be abundance of gas for both blast and boilers.

Of the charcoal furnaces in this region, Boone, Buffalo, and Laurel run a large portion of the time, or altogether, with cold blast, for the manufacture of car-wheel pig iron. The remainder use hot blast all the time. The average yield of the ores is generally stated by the furnace managers to be thirty-three and a third per cent. of iron, thus requiring three tons of raw ore for the production of one ton of iron. The figures, however, taken from the stock books at seven furnaces, for periods ranging from one to five years, give an average yield of 31.94 per cent., thus showing that it has been slightly over-estimated.

It will be noticed that the averages for the different furnaces do not vary greatly, three per cent. being about the limit. This shows the general uniformity in quality among the different ores. Those furnaces situated west of Little Sandy, and which use more or less of the lower block ores, show the least average per centage of iron, while those using the

limestone and kidney ores show the highest yield. It will also be observed that the average yield shown by the furnaces is a considerably less per centage than indicated in the analyses of the ores which have been given heretofore. This is due to no fault of the analyses; they show accurately the composition of the specimens submitted to the chemist. The discrepancy is due to the following causes: 1st. To the loss of iron, which often attends the working of the furnace, through the combination of iron with the slag. This loss is not constant, but is greater as the furnace is working more irregularly and producing more mill iron. In such case there is usually an appreci able amount of iron in the slag. As the amount of slag is often greater than the iron produced, a very small per centage of iron in the slag involves a considerable loss, and materially reduces the yield of iron. This loss amounts to little or nothing when the furnace is working well and producing a foundry iron; for as the pig iron is not pure iron, but contains from five to eight per cent. of foreign matter, carbon, silicon, phosphorus, &c., the gain by these impurities will more than counterbalance the loss by the iron in the slag. In fact the furnace working should show a gain over the analysis when everything works properly. 2d. To the inaccuracy in selecting samples for analysis. The difficulty of selecting perfectly average samples of ores has been already referred to. The method adopted has been to take a great many small pieces of ore, each broken from a different place in the pile or outcrop to be sampled from, until the whole should amount to four or five pounds. The endeavor has been in every case to obtain as near a representative average sample of the whole as possible; but it is probable that, in the majority of cases, it has been actually taken better than the average. The personal equation in the matter of sampling an ore or coal is of great importance, and it almost invariably works in favor of selecting the best specimens, in spite of the fair intentions of the sampler However careful he may be, he will be apt to think that it is unfair to take a sandy or cherty lump of ore or a piece of pyrites in coal, lest it be more than the general average of the

bed. It is a singular feature of human nature, but it exists in every one, whether personally interested in having the ore or coal well represented or not. In addition to this personal bias, it is usually the case that the ore sampled is cleaner and freer from adhering dirt and clay than the average as it is weighed at the furnace scales. This is caused by the sampler usually selecting a clean corner on each lump to chip or break his sample piece from, as he naturally thinks it would misrepresent the ore to take a piece covered with dirt or clay. There is no doubt that the per centage of iron is materially reduced from this cause below what it would yield if the ore could be purchased clean.

Notwithstanding all this, it is believed that the samples of both ores and coals which have been selected for analysis by the different members of the present Survey, approach more nearly to the character of true representative samples than any which have ever before been collected in this State or by the Geological Surveys of many other States. The character of the sample is of as much importance as the accuracy of the analysis, if a true estimate is to be formed of the quality of an ore or coal; and it should be held as requisite for the sampler to be conscientious and unbiased, as for the chemist to be skillful and accurate; and the name of the sampler should be given as well as the chemist. It is because analyses are so often made from small picked specimens representing the very best of the ore or coal, that so many practical men consider an analysis of no value, and charge upon the chemist the fault of misrepresentation which belongs to the sampler. This matter is more important, if possible, in coal than in ore analyses.

The difference which there is between an analysis made from a single lump taken from the center of a bed of coal or from that part of it which is freest from sulphur, and one made from a sample taken by making a number of cuttings through the whole thickness of the bed representing the coal exactly as it occurs, is very great. In the majority of cases heretofore, the former is the kind of sample which has been subjected to analysis.

The average consumption of charcoal per ton of iron in this region ranges from one hundred and forty-five bushels, at some of the best hot blast furnaces, to two hundred and thirty at some of those working cold blast.

The figures from the books at nine furnaces, for periods of time from one to five years, give an average for the whole of one hundred and seventy-nine bushels per ton of pig iron. This requires for its production about four and a half cords of wood, estimating the usual yield at forty bushels of charcoal to the cord of wood. The original forest of this region yields from thirty to fifty cords of wood per acre, with an average of perhaps thirty-five. Each furnace consumes from five thousand to fifteen thousand cords of wood per annum, varying with the length of the blast, thus clearing from one hundred and forty to four hundred and thirty acres of land each year. In 1872, as shown by the tables of production, there were made in this region twenty-four thousand three hundred and twelve tons of charcoal iron, which would require for its production the wood from over three thousand acres of land.

It will thus be seen how rapidly the forests are being destroyed, and how it is that only those charcoal furnaces which are situated on the very largest estates, those of from twelve thousand to fifteen thousand acres and upwards, can be permanent, as they alone afford time for the second growth to attain a size sufficient for charcoal-making before the original forest is exhausted. It is evident, therefore, that in course of time the charcoal iron industry of this region must be supplanted by the manufacture of iron with stone-coal, while the charcoal furnaces will be built further back from the river, where the forests are as yet comparatively unbroken, and from whence the more valuable charcoal iron will bear the higher cost of transportation.

The following table shows the average yield of ore, and the consumption of charcoal, at most of the furnaces of this region. The returns are not as complete as could be desired from all the furnaces, but the number of years from which the averages

are made is given in each case, so that the proper weight can be given to the comparative returns by the reader.

In many cases the figures from which this table was constructed were taken directly from the furnace books, which were kindly placed at the disposal of the Survey. The returns of charcoal consumption are not absolutely accurate for comparison, as there is some variation in measurement at the different furnaces. The charcoal receipts are given in loads of two hundred bushels each, but the size of the wagon-beds, which are counted as holding two hundred bushels, varies somewhat at different furnaces. The consumption of charcoal was of course taken at the furnace measurement in each case. It is believed that this error will not amount to more than a few bushels in the general average. The returns of ore are probably accurate.

Furnace.	Number of years.	Ave'ge per centage of iron in the ore.	Number of years.	Average bushels charcoal to ton of iron.
Bellefont	4	32.23	5	185
Buena Vista	2	33.5	5	141
Buffalo	1	30.6	3	*229
Hunnewell	5	32.38	5	161
Kenton	4	32.8	4	197
Laurel	....	....	4	175
Mt. Savage	....	......	3	164
Pennsylvania	5	31.7	5	194
Raccoon	4	30.4	1	163
Average	....	31.94	....	179

* Furnace working cold blast much of the time.

The ores of this region usually contain such a mixture of ingredients that comparatively little lime is required to flux them. This is usually obtained from either the sub-carboniferous or the ferriferous limestones. At Mount Savage Furnace some limestone is used from the fossiliferous beds of the middle coal measures. The amount used varies from two to twenty-two per cent. of the roasted ore charged, as will be seen by the following table showing the ordinary charges, or so-called half charges, in use at the different furnaces. These are given as they were reported, without any guarantee as to

the accuracy of the weights or measurements. It is probable that the weight of ore is usually pretty correct. The weight of limestone is, in many cases, estimated; and in the measurement of the charge of charcoal, considerable differences exist among the various furnaces; to reconcile which, in tabulating, no attempt has been made. The following table is, therefore, most valuable as showing the proportion of limestone used at the different furnaces, as the ores vary:

AVERAGE "HALF CHARGES" USED AT THE DIFFERENT CHARCOAL FURNACES.

Name of Furnace.	Roasted ore. Pounds.	Limestone. Pounds.	Charcoal. Bushels.	Average number of half charges in 12 hours.
Bellefont	1000	20	33⅓	......
Buena Vista	1700	20	33⅓	......
Buffalo C. B.	750	100	30	26
Buffalo H. B.	950	125	30	28
Hunnewell	1500	60	40	30
Iron Hills	1200	225	33⅓	......
Kenton	1100	240	22	36
Laurel C. B.	650	100	22	38
Laurel H. B.	900	60	22	45
Mt. Savage	1050	40	25	30
Pennsylvania	1250	60	35	......
Raccoon	1000	200	28	26

It will be noticed from the above table, that those furnaces situated west of Little Sandy river, working considerable quantities of the silicious lower block ores, use the largest per centage of limestone. Kenton Furnace, which is compelled to use more of these ores than any other, also consumes correspondingly increased amount of lime. Iron Hills Furnace, working the Lambert ore, shows its silicious nature by the amount of lime which it was obliged to use. The furnaces, on the other hand, which work the upper limestone and kidney ores, consume a very small amount of lime, only ranging from two to five per cent. of the amount of roasted ore.

The ore is prepared for the furnace by a preliminary roasting or calcination. This is, as yet, done altogether in open heaps or piles, so-called kilns. The fuel used is charcoal

braze, fine charcoal, which is pulverized in the manufacture and handling. The ore is piled in pyramidal heaps upon a framework of logs, in alternate layers of ore and fine charcoal. The pile is then ignited at the bottom, and allowed to burn until the charcoal is all consumed, which usually occupies several weeks, when the ore is screened from the ashes and dust, and charged in the furnace. None of the furnaces as yet have roasting ovens or furnaces. This process, as usually conducted, probably offers more room for improvement than any other feature of the iron metallurgy of this region. It is open to serious objections, not the least of which is, that there is no control over the operation after the fire is once started; the whole success is dependent on the judgment of the man who "sets" the pile; if he properly arranges it and distributes the necessary amount of fuel, the operation will go on successfully; if not, there is no help for it, until the pile is all burned out. It is extremely difficult, if not impossible, to roast all portions of the ore alike. The interior of a heap is apt to become too highly heated, while the exterior may be scarcely warmed. There is great danger also of looping or melting the ore before it is roasted. This is quite a serious injury to the ore, rendering it more difficult to smelt, and materially increasing the liability to loss of iron in the furnace, through its entering into combination with the silicious matter present, forming silicates of iron, which are apt to go into the slag. Looped or melted ore is more difficult to smelt, as it is so dense and compact that it is impermeable to the reducing gases of the furnace.

These features are inherent to the system, and no care can entirely remove them; but the custom of roasting many different kinds of ore together, putting in one pile hard carbonate block ores and shelly limonite kidneys, without regard to the fact that they require very different treatment, as is often done, adds another and probably the strongest objection of all. It is a question whether roasting in open heaps is a method suitable for carbonate ores under the best circumstances; but nothing can be more injudicious than to pile indiscriminately,

into one heap, a mixture of carbonate and limonite ores, and then expect to roast them all suitably at one operation. The result is, that if fuel enough be used to properly roast the hard carbonates, the limonites are looped; and if the heat is regulated for the limonites the carbonates will be scarcely affected, and require another treatment. Moreover, the carbonate ores usually contain more sulphur than the limonites, and for this reason they should not be roasted together, as the sulphur escaping from the carbonates is apt to impregnate, more or less, the other ores. This method of roasting is not an effectual one for the removal of sulphur. This can be much more thoroughly accomplished by the use of permanent roasting ovens or furnaces, in which the process can be under complete control, and the heat easily regulated according to the character or requirements of the ore under treatment.

The present inability of the charcoal furnaces to use the hard blue carbonate ores, and continue the regular production of a coarse-grained foundry iron, has been already referred to.

We thus see that by far the greater proportion of all the ore in this region is practically unavailable. If this is ever to be used by the charcoal furnaces, it must be after an improved method of roasting is introduced, by which the sulphur can be effectually removed, and the ore, instead of being looped or melted together, as at present, can be roasted with the admission of air enough to convert it into a porous, easily reducible peroxide.

At present it is regarded as a finality by many furnace managers that the blue ores cannot be worked to produce a hot blast foundry iron, and they are therefore abandoning large quantities of excellent ore of this kind, or else using it in the production of cold blast iron, in which a light color or fine grain is no objection. Where this kind of ore is used and roasted in the ordinary manner, it is sometimes found necessary to roast it two and even three times, before it is all converted into peroxide and ready for the furnace. The bad economy of this operation is readily seen. Any improvement, therefore, which will enable this vast amount of now useless material to

be utilized, will add materially to the wealth of this portion of the State.

The introduction of roasting furnaces and an improved and more intelligent conduct of the process, might not, it is true, completely accomplish this result; but it is an experiment which can be easily tried, is not expensive, and if it did not succeed in making the blue ores available, would certainly show an economy and improvement in the process over the old method which would amply compensate for the slight expense.

Roasting in furnaces or ovens consumes less fuel and costs considerably less per ton than the old method, as well as requires less time. In the roasting kilns used in the Cleveland iron region in England, the ore, a hard, impure carbonate, is roasted in about two days, and about one ton of coal slack is used to roast twenty-five or thirty tons of ore. These kilns are shaft furnaces working on a similar plan to the continuously operated lime-kilns.

The quality of the charcoal pig iron of this region has been before alluded to. Its chemical composition is shown by the following table of analyses by Dr. Peter and Mr. Talbutt:

	Bellefont Mill.	Bellefont No. 1 Foundry.	Bellefont Silver Grey.
Iron	92.962	93.208	89.902
Graphitic carbon	2.100	3.350	2.900
Combined carbon	1.310	.220	.070
Manganese	. . . . .	.054	. . .
Silicon	2.525	2.389	5.082
Slag	.220	1.160	.280
Aluminum	. . . . .	.193	. . . . .
Calcium	. . . . .	.144	. . . . .
Magnesium	. . . . .	.095	. . . . .
Potassium	. . . . .	.047	. . . . .
Sodium	. . . . .	.032	. . . .
Phosphorus	.568	.194	.417
Sulphur	.114	.005	.114
Total	99.799	101.091	98.763

	Pennsylvania Mill.	Pennsylvania No. 2 Foundry.	Pennsylvania No. 1 Foundry.	Pennsylvania Silver Grey.
Iron	94.764	92.856	92.060	90.630
Graphitic carbon	2.900	3.230	2.700	2.500
Combined carbon	.780	. . . . .	.630	.830
Silicon	1.193	2.545	3.104	4.969
Slag	.200	.360	.300	. . . . .
Phosphorus	.860	.817	.740	.741
Sulphur	.033	.046	.033	.040
Total	100.730	99.854	99.567	99.710

	Mt. Savage Mill.	Mt. Savage No. 2 Foundry.	Mt. Savage No. 1 Foundry.	Mt. Savage Silver Grey.
Iron	93.268	91.584	91.502	89.687
Graphitic carbon	3.950	2.600	2.670	2.300
Combined carbon	.770	1.070	.030	.500
Manganese	. . . . .	. . . .	.123	. . . . .
Silicon	1.799	3.058	4.470	5.575
Slag	.160	.620	1.160	.660
Aluminum	. . . . .	. . . .	.128	. . . . .
Calcium	. . . . .	. . . . .	.144	. . . .
Magnesium	. . . . .	. . . . .	.112	. . . . .
Potassium	. . . .	. . . .	.076	. . . . .
Sodium	. . . . .	. . . .	.023	. . . .
Phosphorus	.680	.609	.203	.609
Sulphur	.081	.152	.041	.136
Total	100.708	99.493	100.682	99.467

	Hunnewell No. 2 Foundry.	Hunnewell No. 1 Foundry.	Buena Vista No. 1 Foundry.
Iron	92.368	92.284	93.712
Graphitic carbon	3.690	2.960	2.990
Combined carbon	. . . . .	.690	.210
Manganese	.020	. . .	.056
Silicon	2.515	3.011	1.908
Slag	1.130	.880	.600
Aluminum	.582	. . . . .	.644
Calcium	.048	. . . . .	.104
Magnesium	a trace.	. . . . .	.095
Potassium	.056	. . . . .	.063
Sodium	a trace.	. . . . .	.010
Phosphorus	.684	.474	.380
Sulphur	.026	a trace.	.066
Total	101.119	100.299	100.838

The above analyses are all from furnaces east of Little Sandy river, which use the upper limestone and kidney ores almost exclusively. The analyses are all of hot blast iron. The grades of iron are known as Mill, No. 2 Foundry, No. 1 Foundry, and "Silver Grey" or glazed pig. Mill iron is made when the furnace is working "cold," No. 2 Foundry when working between "cold" and "hot," No. 1 Foundry when the furnace is working "hot," and "Silver Grey" when working too hot. No. 1 Foundry is the most valuable, and is the grade which the furnaces endeavor to produce all the time. It is a free flowing, non-shrinking iron, which is used for castings of all kinds. "Silver Grey" or glazed pig is of the least value. It is so brittle that it can be used for no purpose where strength is required.

It will be noticed that there is a regular gradation in the amount of silicon present in the different grades of pig iron, directly proportional to the relative heat required in the furnace to produce them. Mill iron, which is made with the least expenditure of heat, contains least silicon, while "Silver Grey" contains the most. The poor quality of this iron is undoubtedly owing to the excess of silicon, which renders the iron brittle or "cold-short," and unfit for the puddling furnace, as in puddling the silicon oxidizes to silica, and combines with a large proportion of the iron, causing a great waste of iron, and rendering the process slow and difficult.

These irons are all somewhat phosphatic, but not enough to injure them for foundry purposes; on the contrary, it is probable that the free flowing, small shrinking qualities in this iron are largely due to the phosphorus present. Sulphur is low—0.15 per cent. being the highest in any samples analyzed.

The above statements apply equally well to the iron made at the furnaces west of Little Sandy river, which use the block and lower limestone ores exclusively.

	Boone No. 1 F., hot blast.	Boone No. 2 F., hot blast.	Kenton No. 1 F., hot blast.	Raccoon No. 1 F., hot blast.	Iron Hills No. 1 F., hot blast.	Laurel No. 2, cold blast.	Buffalo No. 1 F., hot blast.	Buffalo Silv. Grey, hot blast.	Buffalo No. 1, cold blast.
Iron	93.212	90.958	92.724	91.668	92.387	92.697	91.656	88,106	94.739
Graph. carbon	2.940	2.164	3.320	2.950	3.340	2.100	2.790	1 950	3.620
Comb. carbon	.060	.116	.660	...	.760	1.000	...	.570	.780
Manganese	.083	.115	.612	.332	.056	...	.084	.014	.056
Silicon	1.634	2.682	2.090	3.817	2.240	1.813	4.106	7.317	.877
Slag	2.460	4.180	.300	1.200	.620	...	.600	.900	.120
Aluminum	.330	.479	.442	.128	.120	...	.399	.165	.060
Calcium	...	...	.184	.075	.120	...	.168	.128	.104
Magnesium	...	...	.190	.122	.056	...	.095	.125	.082
Potassium	...	...	.104	...	.080	...	.086	.048	.048
Sodium	...	...	.004	...	...	...	.016	.002	.041
Phosphorus	.486	.304	.622	.334	.836	.454	.695	.768	.609
Sulphur	.079	not det.	.046	.041	.057	.218	.150	.019	.037
Total	101.284	100.998	101.298	100.667	100.672	...	100.845	100.112	101.773

These irons show a very slight excess in the average amount of phosphorus over those from furnaces east of Little Sandy, but it is small. The superiority of cold blast iron seems, from these analyses, to be due more to its comparative freedom from silicon than any other cause. It is made when the furnace is not working so hot as with hot blast, and those metals, such as silicon, aluminum, &c., which require for their reduction an intense heat, are not reduced to alloy with the iron, but pass into the slag.

THE STONE-COAL IRON MANUFACTURE.

This branch of the iron manufacture, as yet in this region comparatively in its infancy, is destined to become ere long by far the most important industry. The great majority of charcoal furnaces are of necessity, as already shown, short lived through the exhaustion of their timber supply, which happens usually long before the ore supply becomes precarious. The permanent manufacture must then be based upon a supply of fuel which shall be neither precarious nor expensive. Fortunately this portion of Kentucky is richly blessed with an ample supply of a most excellent coal, a coal which the experience of the past six years has proved to stand in the front rank of the iron-making coals of the country. It is a dry-burning non-coking coal, which is used most successfully in a raw state for the manufacture of pig iron. It is known variously as the Coalton or Ashland coal, and is classed as No. 7. Its geological position and equivalency have already been described in

Mr. Crandall's report. It is the Kilgore coal of the old Geological Reports. It is known as the Coalton or Ashland coal, from the fact that it is most extensively mined by the Ashland Coal Company, at Coalton, on the Lexington and Big Sandy Railroad, Eastern Division, about twelve miles back from Ashland, in Boyd county. From the mines of this company the greater portion of this coal for furnace use has been obtained.

In addition, it is mined on the Star Furnace estate, now the property of the Norton Iron Works, of Ashland, and at Willard, Carter county, the present terminus of the Eastern Kentucky Railway, by the Bellefont and Ætna Coal and Iron Company. It is used in this State by the Ashland Furnace, belonging to the Lexington and Big Sandy Railroad, Eastern Division, and by the furnace of the Norton Iron Works Company, both situated in Ashland. It is also used by the Bellefont Furnace, of Ironton, Ohio, and will be used in the large furnaces now being erected by the Ætna Iron Company, near the same place.

As yet the No. 7 is the only coal which has been successfully used as a furnace fuel in this region. An attempt was made several years since to use the No. 3 coal at Hunnewell Furnace, but it was not sufficiently successful to justify a repetition of the trial. A blast of about four months was made, using this coal, but the production did not average over six tons per day, and the iron was of very poor quality, as could have been expected from the character of the coal, which is very sulphurous. It is probable that the working of the furnace when using this coal would have been more successful had the furnace and machinery been adapted to that fuel. They were constructed for charcoal and used for stone-coal without any material alteration. The coal is so sulphurous, however, that it is probable it would always make a poor iron, unless it could be first washed and coked.

The No. 1 coal, which is probably the equivalent of the well-known Jackson coal, of Ohio, which has proved so successful a furnace coal, is found of workable thickness at a number of places in this region, and will probably, on trial, be found to be

well adapted to furnace use. It shows, in some places, of very good quality; but it is, unfortunately, somewhat irregular in its thickness. The following are analyses, by Dr. Peter and Mr. Talbutt, of this coal from the Graham bank, near Willard, Carter county:

	I.	II.	III.
Moisture	3.80	3.50	3.60
Volatile combustible matters	34.50	36.30	35.40
Fixed carbon	58.50	57.30	57.60
Ash	3.20	2.90	3.40
Total	100.00	100.00	100.00
Coke	61.70	60.20	61.00
Specific gravity	1.274	1.269	. .
Sulphur	2.164	1.148	1.065
Sampler	P. N. Moore	P. N. Moore	Geo. Gibbs.

No. I is a sample taken from the whole thickness of the coal, including a pyritous band, which can be rejected in mining. Nos. II and III are taken from the whole thickness of the bed, rejecting this band.

From the above analyses it is evident that the coal is of most excellent quality. The ash and sulphur are both low, and the fixed carbon is high. There can be little doubt that it will make an excellent furnace fuel, equal to or superior to any in this region.

The quality of the Coalton or No. 7 coal varies greatly, and it is at some places irregular in its thickness. The difference in quality is due to the greater or less proportion of sulphur present in the coal. This varies greatly in very short distances. The same mine will show coal in different parts of it of greatly different quality. The per centage of ash is quite uniform, as is the general structure of the coal, which retains its dry burning character throughout; but the sulphur is sub-

ject to rapid variation. The analyses that have been made by Dr. Peter and Mr. Talbutt, of this coal, usually show more sulphur than the coal was supposed to contain, and more than former analyses had indicated. This is due to the different methods of sampling employed. Heretofore the analyses had been made from single lumps, or from several lumps, which were usually taken by interested parties, and probably represented the coal at its best. This has been too often the plan pursued by members of Geological Surveys in other States, and the result has been to generally represent the coals as better than they actually are. The plan pursued by the members of the present Survey has been to take carefully averaged samples. These were made by cutting a large number of small pieces of coal from the whole thickness of the bed, taking them in regular succession from top to bottom, thus representing the coal exactly as it occurs at the place of sampling. Slate partings, or pyritous bands, large enough to be rejected in mining, were not of course represented in the sample, but otherwise impurities were taken if they occurred at the place of the cutting. Wherever possible the sample was taken from a number of rooms in each mine, or, where the coal was not opened, from as many outcrops as possible. The constant endeavor has been to secure samples representing the coal as it actually occurs in the mine. The personal bias already referred to in the matter of ore sampling, probably does not have as much influence in favor of the coals, when they are sampled in the mine in the way just described, for the reason that the cutting is made right through the coal where it is once started, and in the darkness of the mine it is difficult to see what is the exact quality of each piece taken. In sampling coal from a stock pile it is a different and more difficult matter to select a fair average sample; for the personal bias of the sampler then works in favor of the coal. It requires a strong effort of the will to break off a piece of pyritous coal and drop it into the sample bag when the sampler sees it before him in broad daylight. However conscientious he may be, he will be apt to think that perhaps if he takes that iden-

tical fragment of pyritous coal it will be more than the average, and so he will reason in regard to the next piece and the next, until in the end his sample will be much better than the average of the coal.

The following analyses of the No. 7 coal were all made from samples taken in the manner above described. The analyses are by Dr. Peter and Mr. Talbutt. The name of the sample is given with analysis:

	1.	2.	3.	4.	5.	6. Star.
Specific gravity	1.291	1.320	1.336	1.340	1.308	1.377
Water	4.80	5.00	4.06	4.40	3.30	7.70
Volatile combustible matter	34.20	34.50	34.24	31.10	33.30	28.16
Fixed carbon	54.90	55.40	54.70	57.90	57.60	53.04
Ash	6.10	5.10	7.00	6.60	5.80	11.10
Total	100.00	100.00	100.00	100.00	100.00	100.00
Coke	61.00	60.50	61.70	64.50	63.40	64.14
Sulphur	1.312	1.285	1.854	2.095	2.480	1.055
Sampled by	Moore.	Moore.	Moore.	Moore.	Moore.	Crandall.

	7. Star.	8. Star.	9.	10.	11.	12.
Specific gravity	1.290	1.288	1.320	1.340	1.320	1.350
Water	6.40	6.60	6.06	6.40	4.40	3.20
Volatile combustible matter	27.22	34.36	32.94	31.40	38.00	35.06
Fixed carbon	58.88	54.64	54.80	57.66	52.86	54.40
Ash	7.50	4.40	6.20	4.54	9.14	7.34
Total	100.00	100.00	100.00	100.00	100.00	100.00
Coke	66.38	59.04	61.00	62.20	62.00	61.74
Sulphur	.973	.724	1.867	1.670	2.200	2.631
Sampled by	Crandall.	Crandall.	Moore.	Moore.	Moore.	Moore.

No. 1 is an average sample of the coal from the stock-house at Ashland Furnace, taken to represent as nearly as possible the coal as actually used in the furnace.

Numbers 2 to 5, inclusive, are samples, each one taken from several rooms in mine No. 4 of the Ashland Coal Company, above Coalton, in Boyd county.

No. 2 is from several rooms about two hundred and fifty yards from the west end of entry No. 4.

No. 3 from rooms about three hundred yards from east end of entry No. 4.

No. 4 from rooms about eight hundred yards from west end of same entry.

No. 5 from rooms opening into the Dry branch cross-entry.

Nos. 6 to 8 are samples taken from the upper, middle, and lower members of the coal bed at the old Star Furnace mines above the furnace. The samples were taken from the pillars, which had been exposed for some time, and probably contained less sulphur than the freshly broken coal.

No. 6 is the upper, No. 7 the middle, and No. 8 the lower stratum of the coal.

Nos. 9 and 10 are samples from the upper and lower layers of the coal, here consisting of but two members, at an opening on Gum branch of Straight Creek, Mt. Savage Furnace property, Carter county. These samples were selected from coal on the bank, and hence are probably not as accurate averages as those taken in the mines.

No. 11 is a sample from the old Watson drift, on Lost Creek, near Willard, Carter county.

No. 12 is from several rooms in the mine west of Dry Fork, at Willard, Carter county, main entry.

These analyses show the great variation that exists in the amount of sulphur in this coal. In other respects, as will be seen above, the uniformity is remarkable. The per centage of ash is quite uniform. The sample that shows 11.10 per cent. is from the upper member of the coal at Star Furnace, a layer that is not taken down in mining, as it is usually quite sulphurous and slaty.

These analyses were all made from carefully taken samples, and they showed the coal to be more sulphurous than generally supposed, and more than analyses heretofore published had shown. They also indicate a coal poorer than similar coals from other States, judging by the published analyses of them, which, however, had probably been made from picked specimens, or at least there was no description given of the character of the samples from which the analyses were made.

Actual experience with the working of this coal in the furnace, for the past eight years, as will be shown more in detail further on, proves that it is a most excellent iron-making fuel, and that it ranks among the best of the country, although the analyses did not show as well as those of similar coals from other States.

With the view of making a trustworthy comparison with other successful iron-making coals of the country, based upon analyses from samples which were taken in the same way, and were known to be honestly and carefully selected to fairly represent the coal as it actually occurs, not picked to make as good a showing as possible, the Indiana Block, the Big Muddy, Illinois, the Hocking Valley or Nelsonville, and the Jackson, Ohio, coal regions were visited by members of the Survey, and samples selected in the same manner as in all the Kentucky coals.

The following are the analyses by Dr. Peter and Mr. Talbutt:

	1.	2.	3.	4.	5.
Specific gravity	....	1.313	....	1.310	1.310
Water	2.40	2.70	2.68	2.62	3.44
Volatile combustible matter	35.10	36.38	36.32	32.04	31.86
Fixed carbon	55.50	55.64	53.58	58.58	59.54
Ash	9.00	5.28	7.42	6.76	5.16
Total	100.00	100.00	100.00	100.00	100.00
Coke	62.50	60.92	61.00	65.34	64.70
Sulphur	2.373	1.664	1.803	2.472	01.370
Sampled by	Moore.	Moore.	Moore.	Moore.	Moore.

	6.	7.	8.	9.	10.
Specific gravity	1.346	1.303	1.312	1.361	1.322
Water	3.26	3.74	4.40	4.54	3.46
Volatile combustible matter	33.76	36.32	35.08	29.68	36.64
Fixed carbon	54.42	55.74	55.20	57.06	53.80
Ash	8.56	4.20	5.32	8.72	6.10
Total.	100.00	100.00	100.00	100.00	100.00
Coke	62.98	59.94	60.52	65.78	59.90
Sulphur	2.247	1.299	1.659	0.758	1.848
Sampled by	Crandall.	Crandall.	Crandall.	Crandall.	Moore.

Nos. 1, 2, and 3 Indiana Block coal, from near Brazil, Indiana. Samples representing the coal from three different mines. Each sample was taken from several rooms in the same mine, so as to represent it as fairly as possible. These mines rank among the best of that region, and coal from all of them has been, or is now, successfully used in the furnace for making iron. The difference between these analyses and those here-

tofore generally published, strongly points to the probability that they have been made from picked samples.

Nos. 4 and 5 are from two of the best mines in the Big Muddy coal region, near Murphysboro, Illinois. Large quantities of coal from both of these mines have been used in the furnaces at South St. Louis.

Nos. 6, 7, and 8 are samples of the Hocking Valley or Nelsonville coal, from mine near Nelsonville, Ohio. No. 6 from the upper, No. 7 from the middle, and No. 8 from the lower division of the coal.

No. 9 is from the well-known Jackson coal, of Ohio. This analysis compares very favorably with those heretofore published, except that the per centage of ash is much greater.

No. 10 is from the Sheridan mines, Lawrence county, Ohio.

All of the above are excellent fuels, and, with one exception, the Sheridan coal, which has not as yet been tried for iron-making, they rank as the best, or among the best, furnace fuels of the West. The analyses of them heretofore published show much more favorable results; but they have not unlikely been made from picked specimens.

Long trial has proved that these coals work well in the furnace, and that the per centage of sulphur is not sufficient to seriously injure the iron made with them. The conclusion, then, that these analyses point to, is, that a larger proportion of sulphur than heretofore generally supposed, can be present in a coal without destroying its availability for iron-making.

The No. 7 coal, as shown by the analyses already given, compares very favorably with the other iron-making coals, and is superior to most of them. When properly selected for the furnace use, as must be done with all coals, no matter where they are from, it is among the best of the furnace coals in the West.

There is no coal which is of uniform quality throughout its whole range; there is variation in all of them, and the No. 7 coal is no exception. It holds the same general character throughout, but is more or less sulphurous, according to locality.

The first attempt to use this coal for furnace purposes was in 1866, when a considerable quantity of it was sent up the Ohio river to Martinsville, Ohio, and tried in the furnace there. This trial resulted so successfully that in 1867 the Bellefont Furnace was erected at Ironton, Ohio, relying upon this coal for its main supply of fuel, although a considerable proportion of coke is generally used. This was followed, in 1869, by the erection of the Ashland Furnace, at Ashland, and in 1873, by the Norton Iron Works at the same place. These two furnaces are, therefore, as yet, the only ones in this portion of Kentucky which manufacture iron from stone-coal. They are among the most successful and complete furnaces in the West.

The following are the principal dimensions of the two:

	Ashland.	Norton.
Height	60′	67′
Diameter of bosh	15′	18′
Slope of bosh	72°	73°
Diameter of throat	10′	9′
Height of hearth	6′	7′
Diameter of hearth at bottom	6′	6′
Diameter of hearth at top	6′	6′
Number of tuyeres	6	7
Diameter of tuyere	4″	4″
Height of tuyere above hearth	3′ 6″	3′ 4″
Vertical blowing engines	1	2
Diameter of blowing cylinder	7′	7′
Stroke of blowing cylinder	6′	4′ 6″
Diameter of steam cylinder	3′	2′ 8″
Stroke of steam cylinder	6′	4′ 6″
Number of hot blast ovens	5	5
Hot blast ovens—pattern	Player.	Player.
Usual temperature of blast	900°	850° to 1000°
Usual pressure of blast—pounds	8	6 to 7

The Ashland Furnace has an iron-shell stack, resting upon four masonry pillars at the base, between which are the tuyere and casting embrasures. The furnace produces mill iron only. It averages a production of from thirty-seven to forty tons per day. In addition to the native ore, which it receives by the railroad, it uses Iron Mountain ore from Missouri, mill cinder, and sometimes ores from other localities.

For fuel it uses the Coalton (No. 7) coal alone, not consuming a pound of coke after the furnace is filled with that material at starting into blast. This fact is of great interest and inportance, as showing the high rank of the Coalton coal as an iron-making fuel. It is of especial interest for comparison with other dry-burning furnace coals of the West. The far-famed Indiana Block coal has never been successfully worked in the furnace for any length of time without the use of a considerable amount of coke to mix with it, which coke has heretofore been brought all the way from Pittsburg by rail; but lately coking ovens have been erected at some of the furnaces in the Indiana Block coal region, to coke the coal from their own mines.

The Big Muddy coal of Illinois, which is the fuel upon which the iron manufacture of St. Louis is based, and which is an excellent coal, has never been used successfully alone for any length of time. The furnaces of St. Louis have also been compelled to bring coke all the way from Pittsburg to use with the coal.

The Hocking Valley or Nelsonville coal, of Ohio, which is also regarded as an excellent furnace fuel, has not been used alone without some admixture of coke. Only the Briar Hill and the Massillon coal of northern, the Jackson coal of southern Ohio, and the Coalton coal of Kentucky, have been used for any length of time alone, of all the furnace coals of the West.

The Ashland Furnace, in which this coal has proved to be so excellent a fuel, is one of the most successfully managed in the West. On the 20th of June, 1874, it finished a blast of three years and four months duration, during which it made, on a hearth of Mt. Savage fire-brick, forty thousand five hundred and twenty-seven tons of iron; during which time, as already stated, not a pound of coke was consumed after the first filling of the furnace. This is a record such as few furnaces can equal. This furnace stops on Sunday, from twelve to twenty-four hours, so that this production represents a less number of days blowing than the total time of the blast.

The following is the record of this furnace consumption and production for the past five years:

	1870.	1871.	1872.	1873.	1874.
Native ore (roasted) used, tons of 2240 lbs. .	6425	7439	8852	10216	6407
Iron Mountain ore " " "	5630	7533	9463	8095	4758
Other ores " " "	4841	41	1077	868	568
Mill cinder " " "	2250	2731	3675	4941	2723
Limestone " " 2268	5990	5184	6820	7655	4800
Coal (tons of 2000 lbs.) used . .	23466	25166	33923	34499	*19160
Iron made, tons of 2240 lbs.. . .	9316	9509	12105	12741	6710
Tons coal (2000 lbs.) to ton iron, 2240 lbs. .	2.51	2.62	2.80	2.70	2.85
Average per centage of iron in the ore mixture	48.6	53.5	52.4	52.8	46.4
Tons of limestone to ton of ore .	0.30	0.29	0.29	0.31	0.33

* Including 230 tons coke used in starting the furnace.

There is an error in the amount of coal consumed in 1870. It is probably under-estimated about one fourth ton to the ton of iron made. Leaving the consumption for this year out of consideration, as being uncertain, the table gives us for the four years, from 1871 to 1874, inclusive, an average consumption of 2.74 tons (of 2000 pounds each) to the ton of iron from an ore mixture averaging a little over fifty per cent. This corresponds to about 2.44 tons of coal of 2240 pounds each. This consumption is less than that required for a ton of iron, in the majority of the furnaces of the West using other coals of similar character. At Jackson, Ohio, where, however, the furnaces are mostly of small size, the consumption of coal is stated at one hundred bushels per ton of iron, or between three and four tons. At Massillon, Ohio, where the No. 1 coal is used, the equivalent of the Jackson and Briar Hill coals, nearly four tons of coal are consumed to the ton of iron. In Indiana the consumption of the "Block coal" is about three tons, and the ores used are usually of high grade, from Missouri or Lake Superior. All of these are higher than is desirable, and much

more than theoretically required to produce a ton of iron. The volatile matter of the raw coal is considered as having little or no influence in the reduction of the iron, which is effected by the carbonic oxide produced by the combustion of the carbon in the coke, which is therefore the valuable element.

The average per centage of coke in the No. 7 coal, as shown by four analyses from the Ashland Company's mines, is 62.5. The consumption of 2.44 tons of raw coal to the ton of iron is therefore equivalent to 1.52 tons of coke, or about 30 cwt.

When it is remembered that at many of the furnaces of the Cleveland district of England a ton of iron is now made with 18 or 19 cwt. of coke, or less than a ton of coke to the ton of iron, the ores at the same time not yielding more than forty per cent. of iron, the improvement yet to be made in this region will readily be seen.

The average consumption of coal per ton of iron at the Norton Furnace, as will be shown further along, was 2.69 tons of 2000 pounds each, equivalent to 2.4 tons of 2240 pounds. Of this, however, about 8 per cent. was coke used in the early part of the blast. The mixture of ores did not differ greatly from that used at the Ashland Furnace. The consumption of coal is very nearly the same in both furnaces, showing that the quality of the coal is very similar, and that 2.4 to 2.5 gross tons is the amount which as yet the best practice has required in making a ton of iron.

The Norton Iron Works comprise three separate establishments—a blast furnace, a rolling mill, and a nail mill. The works were erected in 1873, but did not go into operation until the spring of 1874. They are among the most extensive and perfect of the kind in the country. The dimensions of the furnace have been already given. It is an iron-shell stack resting upon iron pillars. The hoisting apparatus is an Otis elevator, working in a substantial brick building. Everything about the furnace is constructed in the most thorough and substantial manner. There are five hot blast ovens of the Player pattern, and twelve boilers, each 42″ diameter by 60′

long, which furnish steam for both mills and the furnace. The boilers and hot blast are heated by the waste gases from the furnace. The iron produced at this furnace is mostly mill iron, which is made into nails. There are in the rolling-mill sixteen puddling, and two reheating furnaces. This mill works only for the preparation of plate for the nail machines, of which there are eighty in the nail mill, producing four thousand kegs of nails per week.

For fuel this furnace uses the Coalton (No. 7) coal, from the mines of the company, on the old Star Furnace estate. Some Pittsburg coke was used in starting the furnace into blast, but it was not long continued. The total amount used was not quite 2,000 tons. The No. 7 coal is also used in the rolling-mill, where it proves a very satisfactory fuel in the puddling furnaces. Ore, mostly kidney, is obtained from the Star Furnace lands, and also limestone ore from the old Kentucky Steam and Caroline Furnace estates, which are now owned by the Norton Iron Works Company. In addition to the native ore, a considerable amount of Iron Mountain ore is also used. The following are the statistics of the working of this furnace for 1874. It did not go into operation until the latter part of February, so that these figures represent only about ten months' operations:

Native ore used . tons of 2268 pounds	8592
Iron Mountain ore, " 2240 "	8228
Mill cinder . . . " 2240 "	2417
Limestone . . " 2268 "	7810
Coal . . . . . . " 2000 "	26334
Coke . . . " 2000 "	1930
Iron made, tons of 2240 pounds	10502
Per centage of iron in the ore mixture	54.5
Tons coal and coke (2000 pounds) to ton iron (2240 pounds)	2.69
Tons limestone to ton of ore	0.40

As yet only the No. 7 coal, from the mines of the Ashland and Norton Companies, in the valley of Williams' Creek, has been successfully used for iron-making. The coal has a far wider field than this valley, where it has been so extensively mined, and it is certainly highly improbable that it should only be found of quality requisite for smelting purposes in that narrow basin. It is finely developed to the south and southwest, showing at places as full a thickness and apparently as good quality as where first mined. It has been opened at Willard, in Carter county, on the land of the Bellefont and Ætna Company, and the coal unsuccessfully tried in the Bellefont Furnace, at Ironton, Ohio. The opening was made on the west side of Dry Fork, in a spur of the main ridge, where the coal was thin and quite sulphurous; so much so that it showed readily to the eye that it was impure. The analysis shows 2.63 per cent. of sulphur. It is no wonder that the attempt was unsuccessful. There is a large field north and northeast of this, on Lost Creek, Davy Run, Straight Creek, and on the Mt. Savage Furnace property, where the coal is well developed in thickness, and at many places is of very good quality. It is probable, or almost certain, that it will at many places be found of quality suitable for iron-making. It may not be such at every opening or outcrop, as it is not, where most successfully mined; but there is every probability that abundance will be found of the best quality. It should be remembered that not every room nor every entry of the mines on Williams' Creek, where this coal is best developed, furnishes a suitable coal for furnace uses. It has to be selected for that purpose from different parts of the mine, and the locality of the best coal changes frequently.

With careful prospecting and selection, it is certainly probable that furnace coal will be found at many places where the coal is now either unknown or unopened.

There can be little doubt that eventually the immense stores of this excellent fuel, with which this region is so richly endowed, will be made servicable. There is also little doubt that eventually much poorer fuel will be successfully used in

the manufacture of iron than is now supposed to be possible; and great quantities of this coal, as well as others which have not as yet been tried, will become sources of wealth.

The tendency of modern improvements in metallurgy is to the invention and introduction of appliances whereby more impure fuels than formerly supposed available can be used in metallurgical operations without detriment to the resulting product. Whether this desirable result will be attained through peculiar construction of furnaces, or by the purification of the coals by some cheap process of washing and coking before they go into the furnace, is impossible to say. It is not unlikely that both methods will be successfully introduced.

The quality of the iron made with the No. 7 coal is shown by the following analyses, by Dr. Peter and Mr. Talbutt:

	No. 1.	No. 2.	No. 3.
Iron	91.420	90.899	89.731
Graphitic carbon	2.460	2.560	1.660
Combined carbon	.240	.160	.790
Manganese	.195	.236	.471
Silicon	3.709	5.121	6.308
Slag	.540	.760	1.120
Calcium	.176	.072	.152
Magnesium	.233	.106	.060
Phosphorus	.385	.394	.461
Sulphur	.082	.045	.015
Total	99.440	100.353	100.768

No. 1 is the No. 1 mill iron, from the Ashland Furnace.

No. 2 is the No. 2 mill iron, from the Ashland Furnace.

No. 3 is a grade of foundry iron, only occasionally made at the same furnace.

All the above were made with the No. 7 coal alone, from a mixture of sixty per cent. native ore, twenty-two per cent. of Iron Mountain ore, eighteen per cent. mill cinder.

STATISTICS OF IRON PRODUCTION.

Below will be found the statistics of the pig iron production of this region for the five years, 1870 to 1874, inclusive. These figures have, in nearly every case, been obtained by a per-

sonal inspection of the furnace books, which have always been kindly placed at our disposal. In a few cases it was impossible to obtain the exact figures, owing to the careless manner in which accounts were kept, or to transfers of furnace property from one owner to another. In these cases the production is given as estimated from the best data that could be had, and the figures are marked with a star (*), showing that they were not as trustworthy as the others. It is believed that this is the most complete and accurate table of statistics of this region ever published, notwithstanding the few errors which it contains.

TABLE SHOWING THE PRODUCTION OF PIG IRON (GROSS TONS) IN THE KENTUCKY DIVISION OF THE HANGING ROCK IRON REGION, FROM 1870 TO 1874.

CHARCOAL IRON.

Furnace.	1870.	1871.	1872.	1873.	1874.
Bellefont	3217	2790	3304	2850	3600
Boone	*1200	*1400	not in blast.	not in blast.	not in blast.
Buena Vista.	3448	2808	3800	3600	4113
Buffalo	1407	1258	2262	1756	*1042
Hunnewell	3059	2265	4322	3812	4371
Iron Hills	not in blast.	not in blast.	not in blast.	141	822
Kenton	1250	1334	2865	2300	3525
Laurel	775	1890	1850	1748	1300*
Mt. Savage	not in blast.	2293	2707	3000	2017
Pennsylvania	2110	1592	1847	2213	1751
Raccoon	*750	882	1247	1467	1320
Total charcoal iron	17216	18512	25204	22887	23861

STONE-COAL IRON.

Ashland	9316	9509	12150	12741	6710
Norton	not in blast.	not in blast.	not in blast.	not in blast.	10502
Star	1302	1958	1643	959	not in blast.
Total stone-coal	10618	11467	13748	13700	17212
Total pig irons of all kinds	27834	29979	38952	36587	41073

*Not from furnace books. Estimated from the most reliable data at command.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

REPORT

ON THE

GEOLOGY OF MENIFEE COUNTY,

BY A. R. CRANDALL.

REPORT ON THE GEOLOGY OF MENIFEE COUNTY.

Menifee county has an area of about two hundred square miles. It reaches from the Licking river to Red river, along the Morgan and Wolf county lines, on the east and southeast, and extends, in a narrowed and somewhat irregular outline, into the valley of Slate creek, to the westward. As will be seen from the accompanying map, the drainage of the county is effected by Beaver creek and its branches; by Salt Lick, the head waters of which are within the county, forming a valley that leads into Bath county on the north; by Clear Fork, Hawkins Branch and other branches of Slate creek, which rise in the western part and flow into Montgomery; by the greater part of Indian and Gilladie creeks, tributaries of Red river, on the south; and by some of the branches of Blackwater creek on the east. The Licking river forms the boundary from the mouth of North Fork to the mouth of Beaver creek, and drains a narrow belt along its tortuous course.

The area of the county is therefore made up of several drainage basins that open outward from the central part. These basins or main valleys are bounded by high ridges, which, together with the almost numberless minor ridges and spurs that determine the local drainage, cover a large part of the area, the main valleys being a complicated system of drainage by multiplied ramifications of narrow valleys, rather than basins, with broad bottom lands.

Geologically the county is stretched across the outcrop of the lower members of the coal measures, and nearly across the belt of the Lower Carboniferous rocks, as represented by the Sub-carboniferous limestone and the Waverly shales and sandstone. This fact, more than any other, carries with it the explanation of the character of the surface, as already de-

scribed; for it brings the hard Conglomerate sandstone of the coal measures in that relation to the surface of the country which makes it the most important factor in the determination of the character of the drainage. The result is what has been described. A general inclination of the rock beds to the east and southeast varies somewhat the results of erosion, as represented by the valleys in the different parts of the county; but the variation is one of degree rather than of kind; for the type of valley, as seen in the middle and eastern part, where the ridges are broad and the cliffs of Conglomerate hem in the narrow valleys, is still preserved on the head waters of Slate creek, where the Conglomerate cliffs, capping the hills, preserve the steepness of the hillsides, and continue the system of ridges and spurs, but with narrowed tops and broader valleys, out into the belt of the Lower Carboniferous rocks. The cliff-making, Sub-carboniferous limestone below the Conglomerate, although no more than forty to sixty feet thick, serves to extend this system beyond the present boundary of the Conglomerate.

The causes which lead to the disposition of the main valleys in a somewhat radiate order, are also closely connected with the geology of the region. Between the hard magnesian and cherty limestone of the Upper Silurian, and the cliff-making, Sub-carboniferous and coal-measure rocks, about five hundred feet, mostly of shaly rock, is interposed—the Devonian black shales and the Waverly shales and sandstone. As might be supposed, this gives rise to a broad valley, having for its boundary the inclined Silurian beds, on the one side, and the receding edges of the Waverly beds, capped by the harder rocks above, on the other side.

Long-continued erosion has widened and diversified this valley, cutting in advance of the receding crests of limestone and conglomerate the smaller valleys that head against Beaver creek and Salt Lick. Thus, the dividing ridge between Slate creek and these streams has come to have a north and south direction, rather than northeast and southwest—the general direction of the line of outcrop. But this

main ridge terminates southward in another main ridge, having its general course east and west, from which the waters of Slate and Beaver flow northward, and the tributaries of Red river southward. The westward extension of this ridge is a continuation of the boundary of the Devonian and Waverly valley already described. The eastward extension, as also the sudden change in the direction of the boundary of Slate creek valley, is explained by another set of conditions. Variations, both in the direction and the steepness of the inclination of the rock beds, becoming important factors in the determination of the direction of the drainage along this ridge. The general eastward dip of all the rocks in this region is modified by a depression which coincides in general with the Red river valley, and also by a slight depression in the direction of the Licking river. This east and west ridge follows the crest of an undulation which has its axis nearly at right-angles to the general outcrop line of the coal measures. It represents an elevation along which the coal-bearing rocks are preserved to the westward, somewhat beyond the general boundary of these rocks, and at the same time it reduces the width of the valley that lies between the coal-measure and the Silurian rocks.

The exact amount and the details of the variation from the general eastward inclination of the several rock formations found in Menifee have not been ascertained, the limited time and means at command forbidding any attempt at accurate measurement. The depression and consequent dip towards Red river is apparent to the most casual observer. That towards the Licking is less noticeable. Mr. Joseph Leslie, in giving the results of his observations, made under the direction of Professor Owen,* speaks of a number of undulations of the rock beds along the outcrop of the coal measures corresponding generally with the drainage basins leading to the westward. A profile section drawn by him illustrates this feature, and gives approximate measurements of these undu-

* Volume IV, page 456, old series.

lations. Not having an opportunity to study this profile section, it can only be referred to in this report in general terms.

These waves, at right-angles to the outcrop, doubtlessly anticipated the drainage of the country by the formation of geological valleys. The thickening of the beds above the Conglomerate to the eastward, and, finally, the change of the general dip, has caused the drainage to be westward along these geological valleys. In this last respect the thickening of the coal measures east and southeastward is more important, as a factor, than it has been heretofore recognized to be; but as few of the facts that come under this head are found in Menifee, it is only necessary to refer to it in this report.

The Lower Carboniferous belt, as shown in this county, is not entitled to particular notice, except in connection with the topography; and under this head the descriptions already published will suffice to give the general reader a clear notion of the relation of the rocks which it represents to the various economic questions involved. (See report of Mr. Lesley on the topography and geology of the country along the outcrop line of the eastern coal fields, volume IV, old series; also report on the geology of the proposed line of the Elizabethtown, Lexington and Big Sandy Railroad, from Mt. Sterling to the Big Sandy river, volume II, second series.) A glance at the accompanying profile section will show the relation of the rocks of this belt to those of the coal measures above, and also to those of the Devonian and Silurian ages below. The section is drawn to illustrate, in a general way, the succession of beds as found in Menifee and the adjoining counties to the northeast and southwest, and more especially to show the geology along a line from Jeffersonville, in Montgomery county, by Frenchburg, to Blackwater creek, near Sexton's Mill. The section is necessarily somewhat diagrammatic, the thickness of the various beds not having been ascertained at all points along the line. It is still more so as to the rocks below the drainage, the thickness being assumed to be the same as where exposed. The representation is made to aid those who have not been accustomed to trace the rocks

below the surface. It should also be stated that the profile is largely diagrammatic for the Blackwater region, the plan for having a complete survey of Menifee not having been carried out.

The coal measures, as shown in the western part of the county, are represented by a shale series and by the Conglomerate sandstone. The former has come to be known as the Sub-conglomerate shale formation, and the coals found in these beds are known as the Sub-conglomerate coals. In this report the term is used without reference to any general classification of the Carboniferous rocks of this field.

In Greenup and Carter it was found that these shales were present, though not always separated from the shales above the Conglomerate, the Conglomerate sandstone being entirely wanting near the Ohio river, in places, but becoming prominent to the southwest.* In that region the lower limestone ore, a thin coal, and a thick bed of non-plastic fire-clay, are included. In this region this shale series is much more prominent; and being surmounted by a great mass of Conglomerate sandstone, it includes nearly all the productive coal and iron-bearing rocks of Menifee.

The fire-clay bed seems to have fallen off in importance in proportion as the Sub-conglomerate shales become more prominent, the only trace of it in this region, so far as known, being an occasional fragment found upon the surface. These fragments may lead to the discovery of local deposits of this clay. On the other hand, the coal deposits are increased in something like the same proportion. This increase does not always carry with it a corresponding increase in economic values, as will be seen by reference to sections 3 and 4, plate 1 (section plates accompanying this report), in which the number of beds is increased without adding greatly to the thickness of workable beds. Generally, however, the deposit is found mostly in a single bed of what proves to be an exceptionally pure coal of workable thickness.

*Report on the geology of Greenup, Carter, and Boyd counties, and a part of Lawrence, volume II, new series.

The limestone ore bed also proves to be an important deposit, both from the quality and the abundance of the ore. Whether the close association with a coal, apparently well adapted to the smelting of iron ore, gives an additional economic value to both the coal and ore, remains yet to be determined by practical experiment.

The nearness to market is an important factor in any view of the economic value of the coal of this region. Already reached by the narrow-gauge railroad from Mt. Sterling, this field ought, from all the conditions of the case, to supply a large part of Central Kentucky with fuel, and that, too, at much more reasonable rates than has been heretofore exacted, until the heavier deposits of more remote regions are reached by this or other railroads; and even then the nearness to market will warrant a competition with more distant fields, until the best deposits of this region have been exhausted. For the same reasons, the Slate creek coal region is of more immediate importance than that of the central part of the county, although the actual coal area on Slate creek is comparatively small, the coal being found near the tops of the narrow ridges. (See profile section.)

Sections 1 and 5, plates 1 and 2, show the position of the main Sub-conglomerate coal, and also the thickness at the two points indicated. The outcrop of this coal is found at this level, wherever the rocks of this horizon are exposed, in the Slate creek valley. Not being mined, or being opened for local use only by benching, the thickness is rarely shown. It is probable, however, that an average thickness like that at the head of Bull Fork will be found in this region, including the main ridge between Slate and Indian creeks, and between Slate and Beaver.

In this valley the limestone ore is not exposed as frequently as further to the eastward, although there is good reason to suppose that it will be found, in its usual variable thickness. at the top of the Sub-carboniferous limestone, over the most of this region. As yet, no effort has been made to determine the value of this ore in this valley, fragments upon the surface

being the only means of judging as to the range of the bed, as also, for the most part, of the thickness.

Sections 2, 3, and 4, plate 1, show a considerable variation in the character and thickness of the Sub-conglomerate series on Indian and Gilladie creeks. At the head of Indian creek the thickness continues to be about the same as on the head waters of Slate, while near the Red river and in the ridge eastward, between Gilladie and Beaver creeks, an increased thickness is found, and also an increased number of coals. Near the mouth of Indian creek, in Powell county, the thickness of the Sub-conglomerate shale series exceeds one hundred feet. Near the mouth of Gilladie creek the shales measure one hundred and twenty-five feet, as shown in section 4.

Section 3, on the farm of Green Gibbs, on Muddy Fork of Indian creek, shows a local feature that has been thought to promise better results from coal mining than elsewhere in this region. A considerable thickness of highly bituminous shale, in some parts an impure coal, gives to the unpracticed eye the appearance of a heavy coal deposit. Nearly the same feature, but in less thickness, is shown on one of the branches of Leatherwood Fork of Indian creek, a little to the westward. At the head of Cane creek a considerable thickness of cannel slate is found at the base of the shale series. There appears to be nothing in these beds to warrant any expectation of local deposits of exceptional value. On the contrary, it may be found that the impure coal of this locality is the equivalent of the coal of section 1. If this should prove to be the fact, then the area of the workable coal would be somewhat reduced. This feature appears to be local, however, and the main coal in workable thickness is found at the head of Leatherwood Fork, and also at a number of points on East Fork of Indian creek.

The sections on Gilladie creek show an increased number of coals, and a change in the relative position of the main bed. Whether this last fact is owing to a decrease in the importance of the coal of section 1, or to an increase in the

thickness of the shales below this coal, is not made clear from the facts at hand. It is quite probable, however, that one of the upper beds is the equivalent of the Bull Fork coal. No openings have been made in this locality to determine the real thickness of these beds. The exposures are such, however, as to show that the upper beds only may be expected to prove valuable.

Near the mouth of Chimney-top creek, in Wolfe county, a section similar to section 4 is found. Coal of very superior quality has been shipped in small quantity to Mt. Sterling from the upper beds. The coal was obtained by benching. No authentic information has been gathered as to the exact thickness of the beds, which are now mostly covered.

The limestone ore is present in all this region, as is shown from the fragments on the surface. It is exposed in large blocks, particularly on the left fork of Gilladie creek, and in the ridge between Middle and Leatherwood Forks of Indian creek. Specimens have been sent in for the State cabinet.

Sections 6 and 8, plate 2, show the extremes in the thickness of the Sub-conglomerate shales in the valley of Beaver creek. A comparison with the sections near the Red river shows a decrease in thickness northward from that river; but it will be seen that, north of the main east and west ridge (known as Dry Ridge), the place of the main coal is the same as at the head of Slate creek, and that the decrease in the thickness of the shales is from the absence of the upper beds; the coal on Brushy creek, near Old Beaver Furnace, being immediately under the Conglomerate cliff. Further to the northeast, in Morgan county, this coal is again separated from the Conglomerate sandstone by shales. South of Dry Ridge, as has already been stated, the increase in the thickness of the shales appears to be mostly below the main coal. The evidence on this point is somewhat conflicting. It is an important matter only as it relates to the more general question of the equivalency of the coal beds to the south and southwest, where the Sub-conglomerate shales become still more

prominent. It was the opinion of Mr. Leslie* that the lower part of the Conglomerate, changed in character to shale and shaly sandstone, and containing several beds of coal, contributes to the thickness of the Sub-conglomerate beds in this direction. In Menifee the variation in thickness of the Sub-conglomerate shales is not accompanied with a corresponding variation in the thickness of the Conglomerate sandstone. On the contrary, in the Red River valley, where the shales are the most prominent, the Conglomerate is also at its maximum thickness, as shown near the mouth of Gilladie creek, the Conglomerate being more than 200 feet thick at this point, the shales reaching 125 feet, and including four coal seams, the number reported by Mr. Leslie to the southwest.

It will be noticed that the position of the cannel coal in sections 3 and 4 indicates a thickening of the lower part of the shale series. On the other hand, the coal in section 6, near the base of the shales on the Beaver creek side of the ridge, appears to be the equivalent of the Bull Fork and Hawkins Creek beds, sections 1 and 5.

In the valley of Beaver creek, except perhaps along Dry Ridge, where the shale series is in considerable thickness, only one coal bed of importance will be found. The sections of plate 3, together with those already referred to, show the position of this bed. In thickness it is not uniform, varying where exposed from twenty inches to thirty inches, at the outcrop.

The limestone ore is exposed at a great number of places in Beaver Creek valley. In the immediate region of Old Beaver Furnace it was formerly opened and worked. (See sections 13 and 14, plate 3.) In the region of Clear Creek Furnace it is now obtained in abundance for furnace supply. (See sections 7, 12, and 15.) The region near the head of Beaver creek promises, so far as surface indications go, to become a more important iron ore region than the localities already mentioned. Sections 6, 9, and 11 show the surround-

*See report on the Topography and Geology of the Western Margin of the Eastern Coal Field of Kentucky, vol. IV, old series, page 454.

ings of this bed as noted in this region. On the Old State Road branch, above Frenchburg, the ore is particularly abundant on the surface, as also at some points along the face of the ridge between the upper Beaver valley and the head of Salt Lick.

Section 10, near the head of Beaver creek, and section 16, near the mouth of the same creek, show a feature which is not uncommon in the Sub-carboniferous limestone of this region—a bed of so-called lithographic limestone, varying from a few inches to two feet in thickness. In the latter region this band is exposed at a number of points; and from Mr. McMurtry's quarry, on the opposite side of the Licking river, blocks were some time since obtained and tested for lithographic use, with satisfactory results. The band is not so uniform in quality, where seen, as to insure equally good results without careful selection.

The valley of Salt Lick is not properly within the coal region, the westward boundary ridge being entirely Sub-carboniferous and Devonian. But the main ridge, between Salt Lick and Beaver creek, is capped by the Conglomerate sandstone with the underlying coal and iron-bearing shales, giving to this valley whatever advantages the coal and iron deposits of this ridge may offer. On Clear creek, a branch leading against this ridge, an iron industry has already sprung up, Clear Creek Furnace having been in successful operation for years previous to the late financial crisis. (See report of Mr. Moore on the Geology of the Red River Iron District.)

East of the Beaver Creek basin the Sub-conglomerate beds are below the drainage, except near the Licking river. Most of that part of Blackwater creek which is within Menifee has its bed in the Conglomerate sandstone. The Sub-conglomerate beds are, therefore, of little economic value east of the Beaver Creek valley. In this part of Menifee the hills are capped by the shales above the Conglomerate. (See profile section.) These shales usually include one or two coals. In this belt no coals of considerable thickness have been observed. Eastward, in Wolfe and Morgan counties, the Con-

glomerate falls below the drainage, and the whole height of the hills is made up of the rocks of the productive coal measures.

The following table of analyses by the chemists of the Survey, Dr. Peter and Mr. Talbutt, shows the quality of the Menifee coal. The analyses were made from samples carefully taken to represent the whole thickness of the bed at the several points:

	Adams' Bank, Old State Road, Branch of Beaver Creek.	Hawkins' Creek Coal.	Brushy Creek, Steele's Bank.	Bull's Fork Coal, Main Bank.
Moisture	5.00	2.94	3.80	5.00
Volatile combustible matter	32.40	33.06	38.60	39.06
Fixed carbon	58.40	56.60	52.00	55.94
Ash	4.20	7.40	5.60	2.76
Sulphur	.614	.997	not determ'd.	1.199
Specific gravity	1.300	1.319	1.301	1.300

SOILS.

The soil of Menifee is mostly sandy loam. Where the shales below or above the Conglomerate supply the greater part of the surface material, the soil is more clayey. The disintegration of the Conglomerate sandstone, the most prominent rock of the greater part of Menifee, gives to the soil a large per cent. of coarse sand. The presence of the Subcarboniferous limestone, no doubt, adds considerably to the richness of the soil of the valleys where it is exposed; while the woodlands, which comprise by far the greater part of the county, are rich in vegetable mould. The unevenness of the surface is unfavorable for extensive tillage. Pasturage should become an important part of husbandry in this region. The steep hillsides are particularly unsuited to tillage. Rich in vegetable mould when first cleared of timber, it takes but a few years of plowing and washing to render them barren, and, for a time, nearly worthless. When this result has been reached, it is too late to seed for pasture. With the system, or want of system in farming, that tends to this result, there is nothing to do but to clear another tract, and to sacrifice it in the same way. It is largely owing to this way of farming

that the apparent barrenness of the hill country, where cleared, so belies the natural fertility of the soil. Well directed enterprise in farming would do very much to offset the disadvantages of a hilly and broken surface.

TIMBER.

The timber of Menifee includes the following species, besides some others, which doubtless have been overlooked, no time having been at command for a special study of this subject. For a general view of the distribution of species, see report on the Timber Growth of Greenup, Carter, Boyd. and Lawrence Counties, vol. I, new series:

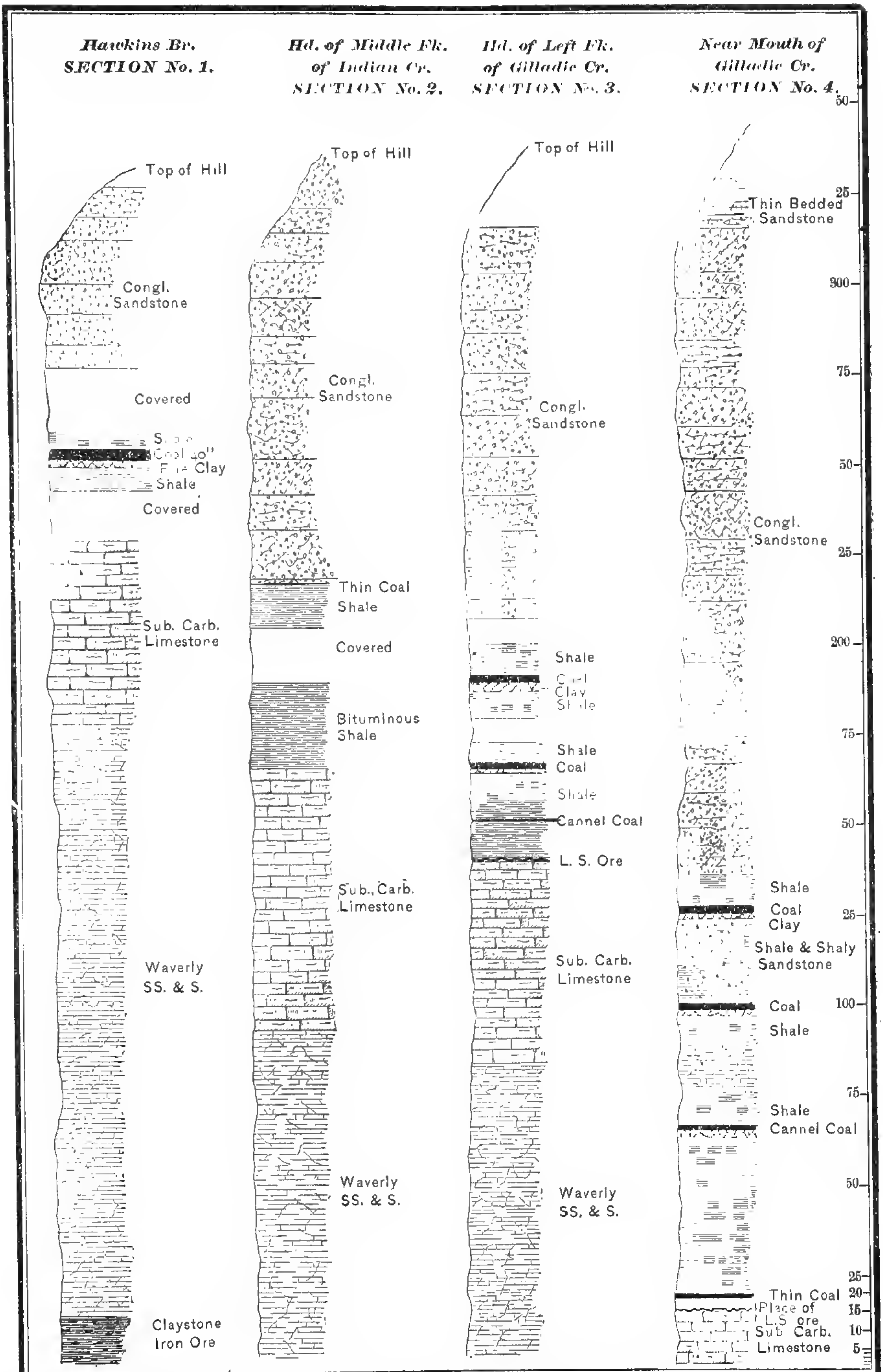
First in importance, both in value and in abundance, is the white oak (*Quercus alba, L.*) The black oak (*Q. tinctoria, Bartram*) is abundant on the hillsides. The red oak (*Q. rubra, L.*) has about the same range as the black oak, but is less abundant. The chestnut oak (*Q. prinus var. montacola*) is abundant along the ridges. In the report referred to above, this species was, by some mistake, given as *Q. castanea.* The pin oak, or perhaps the scarlet oak (not in season to determine species), generally present on the low spurs between the smaller streams. The Spanish and the laurel oak (*Q. falcata L.* and *Q. imbricaria, Mx.*) are found along the border of the county on Slate creek. The beech (*Fagus sylvatica, L.*) is abundant in the valleys generally. The sugar tree (*Acer saccharinum, Wang.*), the white or soft maple (*A. dasycarpum, Ehrh.*), and the red maple (*A. rubrum, L.*) are present—the first in considerable numbers, the last only met with here and there as a single tree. The tulip tree (*Liriodendron tulipifera, L.*), generally known as the yellow poplar, is abundant on the hillsides. The chestnut (*Castanea vesca, L.*) is found in great numbers towards the top of the hills. The hickories (*Carya tomentosa, Nutt., C. alba, Nutt.*, and *C. amara, Nutt.*) are well represented, and in the second growth, as on the hill west of Old Beaver Furnace, they often largely predominate, the first two species being most abundant. The black gum or gum tree (*Nyssa multiflora, Wang.*) is found

everywhere in small numbers. The white ash (*Fraxinus Americana, L.*) and the linden or linn, as it is sometimes called, are found in some of the valleys. The former is exceptionally abundant in the valley of Leatherwood Fork of Indian creek. The buckeye (*Æsculus glabra, Willd.*) is found in the larger valleys; the sycamore (*Platanus occidentalis, L.*) has about the same range. The elm (*Ulmus Americana, L.*) ranges from the creek bottoms well up on the hillsides. The black walnut and the white walnut grow in all the main valleys. The locust tree (*Robina pseudacacia, L.*) is seen occasionally on the hillsides. The cucumber tree (*Magnolia acuminata, Lam.*) is seen occasionally on the heads of streams, but rarely large enough to be valuable for lumber. The mulberry (*Morus rubra, L.*) is found along the base of the hills. The sassafras tree (*Sassafras officinale, Nees.*), the dogwood (*Cornus florida, L.*), and the sourwood (*Oxydendrum arborinum, D. C.*) are each of frequent occurrence. The redbud (*Circis canadensis, L.*) is occasionally, and the ironwood (*Ostrya virginica, L.*) is rarely, found on the hillsides. The hornbeam (*Carpinus Americana, Mx.*) and the willows are scattered along the streams. The holly (*Ilex opaca, Ait.*) is limited to the vicinity of the most precipitous cliffs. The pawpaw is abundant on the water-courses. The persimmon is less abundant.

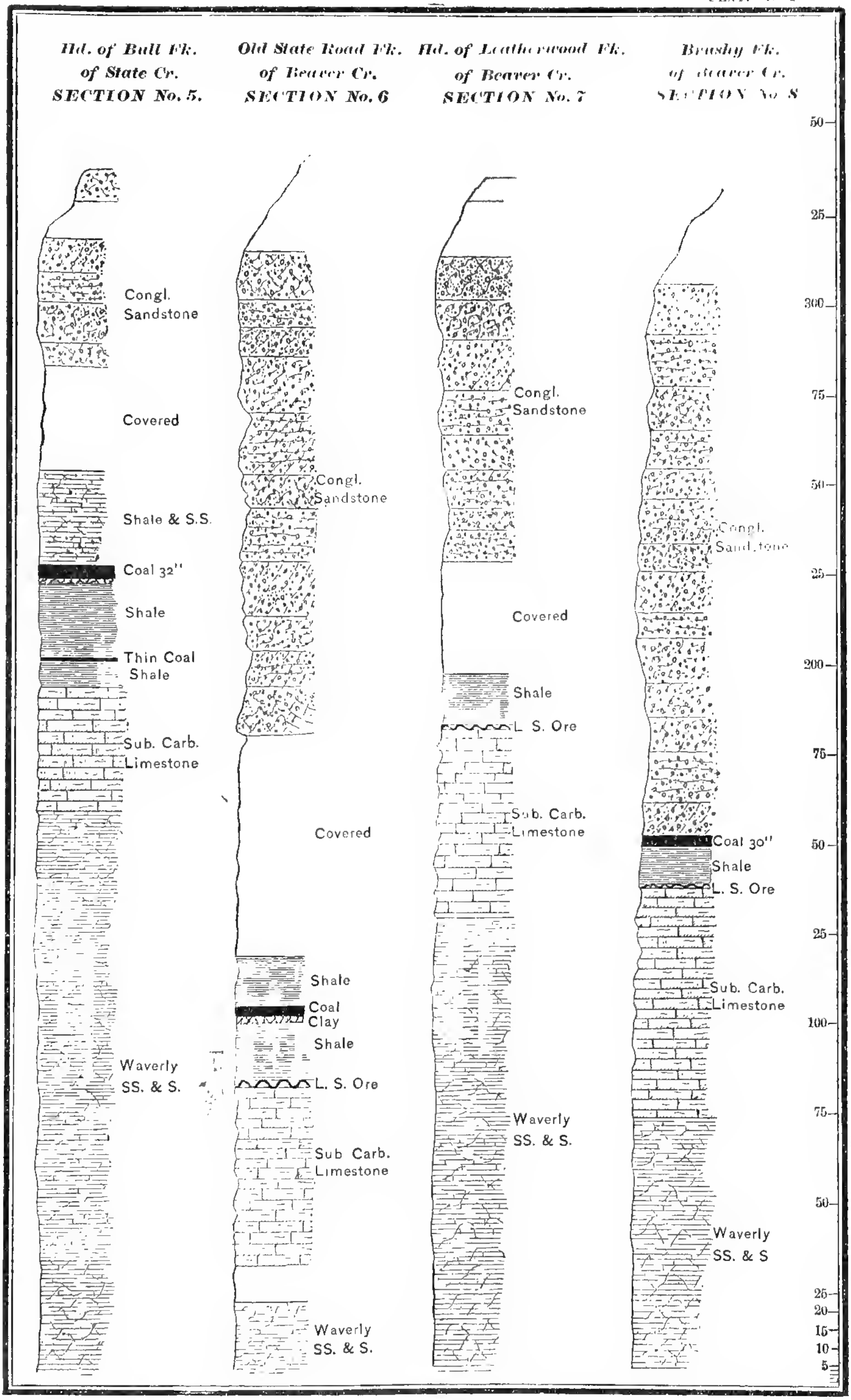
Of the cone-bearing trees, the hemlock (*Abies Canadensis, Mx.*) and the yellow pine are the most abundant—the former on steep rocky surfaces near the streams, the latter along the ridges. The white pine (*Pinus strobus, L.*) is abundant in some parts of the Red River valley, but only a few trees of this species fall within the county line. A few red cedars (*Juniperus virginica, L.*) occur near the limestone cliffs or ledges.

The timber of Menifee, as of all the hilly counties, should be held in high estimation among those things that go to make up the natural wealth of the region.

PLATE No. 1.



N. Y. Map and Relief-Line Eng. Co., 17 Warren St.



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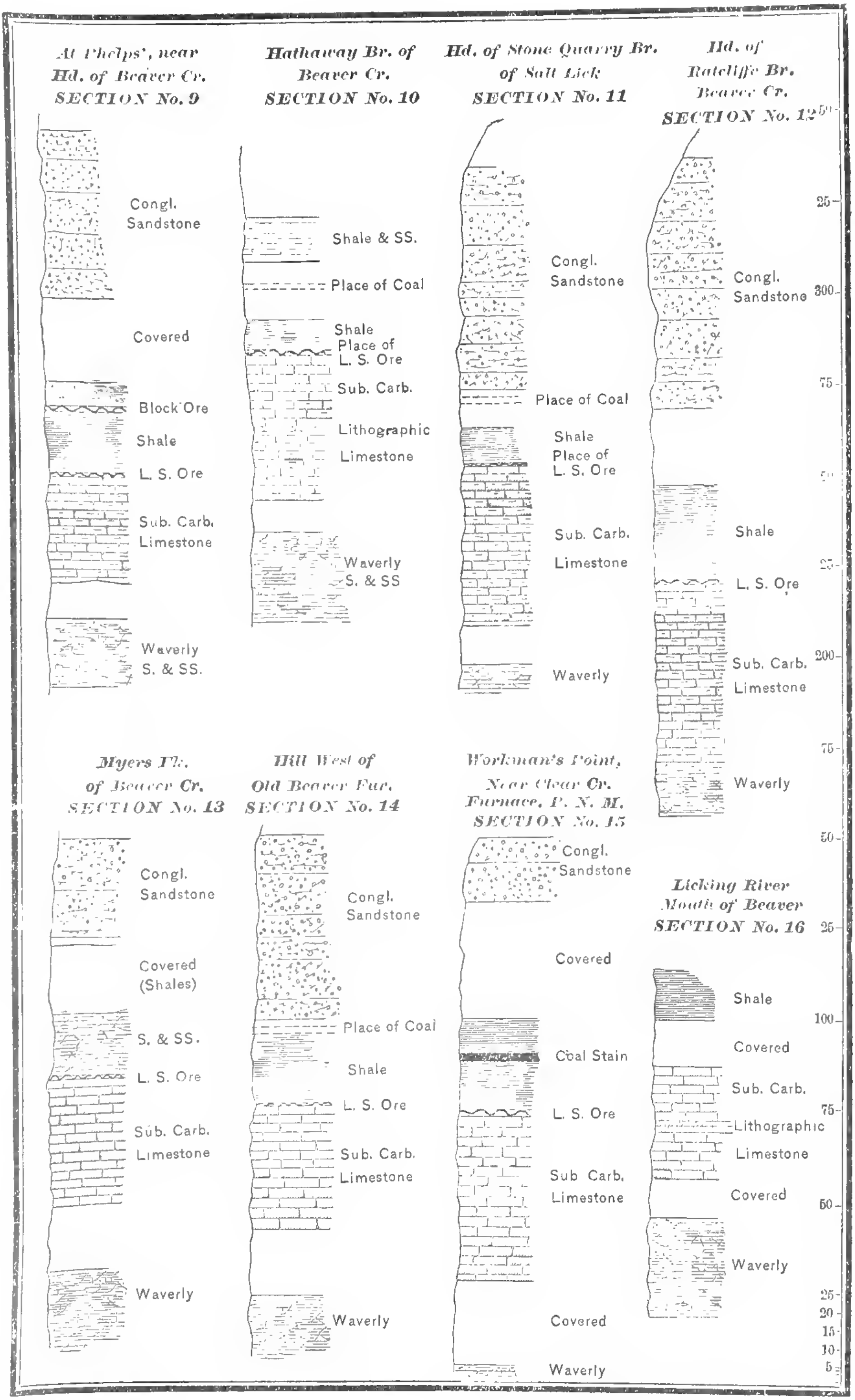

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GEOLOGICAL SURVEY OF KENTUCKY

N. S. SHALER, Director.

REPORT

ON THE

IRON ORES & THE IRON MANUFACTURE

OF THE

KENTUCKY RED RIVER IRON REGION.

BY P. N. MOORE.

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ON THE IRON ORES AND THE IRON MANUFACTURE OF THE KENTUCKY RED RIVER IRON REGION.

This region takes its name from the Red river, a branch of the Kentucky, upon which one of the earliest iron furnaces in the State of Kentucky, or in the West, was established.

The name Red River iron was first applied only to that made by those furnaces situated within the area drained by that stream; but, as the reputation of the iron in the markets of the West increased, the name was also applied to the product of furnaces beyond the neighborhood, but using the same ores, until the Red River Iron region grew to include territory drained by the Kentucky river itself, and its minor branches, the Red river, and the Licking, with some of its minor branches. It includes portions of Estill, Powell, Lee, Menifee, Bath, and Montgomery counties.

A more comprehensive definition of the region, as the term is used in this report, is to describe it as all that region lying between the Kentucky and Licking rivers, in which the Subcarboniferous or St. Louis limestone is found above the drainage. It is, therefore, an area about thirty-five miles long by ten miles wide, lying along the western border of the eastern Kentucky portion of the great Allegheny coal field. The name, as applied, is limited arbitrarily to the area between these rivers, because there are as yet no furnaces situated south of the Kentucky or north of the Licking river for a considerable distance, until the iron district of Carter county, of the Hanging Rock Iron region, is reached.

In discussing this region, there will be described—

I. The iron ores.

II. The iron manufacture.

I. THE IRON ORES.

The geological structure of a large portion of this region is described in detail in the report of Mr. Crandall upon the geology of Menifee county. The general type of geological structure, as there described, prevails over all this region. For the details as to special localities, the reader is referred to Mr. Crandall's report; but a few words of general description of the principal rock formations in this region will be given here, as being necessary to a correct understanding of the position of the ores to be described.

The rocks, which will be met with in almost all of the hills where the main ore of this region occurs, are, in a descending order, as follows: the Conglomerate sandstone and the underlying shales, with beds of coal, of the coal measures; the Sub-carboniferous or St. Louis limestone, and the Waverly sandstone of the Sub-carboniferous formation.

The Waverly, a fine-grained shaly sandstone, usually of a light olive-green tint, is the bed rock in which the streams flow, over the greater portion of the region under consideration, although toward the western border the Devonian black shale occupies this position, and the Waverly rises above the drainage. The Waverly has usually a thickness of about three hundred feet in this region.

Above the Waverly the Sub-carboniferous limestone is found, ranging from thirty or forty feet in thickness in the northern, to one hundred feet or more in the southern part of this region. Topographically this rock is not of great importance, except towards the southwest, where it is at its maximum thickness, and lies very near the top of the ridge, the Conglomerate and other overlying rock having been nearly all removed. Further to the east and northeast, where it lies nearer the drainage level, and the Conglomerate covers a large proportion of the surface, the limestone is thinner and more rarely exposed, being generally covered by the talus from the overlying Conglomerate.

Economically, however, the limestone is of great importance, as it is the rock upon which rests the ore of this region.

which has given to it its reputation, and in itself it is valuable for building purposes, and furnishes a flux for the furnaces of the region.

The Conglomerate is the most conspicuous, and, topographically, the most important, of the members of the rock series of this region. It caps the most of the ridges, except on the extreme western border of this region, gradually descending towards the east and southeast, until it finally reaches the drainage level. It is a massive, pebbly sandstone, usually from one hundred to two hundred feet in thickness. Over part of this area it occurs in two members, with coal-bearing shales between. When this is the case, the upper Conglomerate is the most prominent, while the lower is usually not over thirty or forty feet thick, and occurs quite close down to the limestone, with sometimes not over ten feet of space between them.

The ores of this region belong to the class of earthy carbonates, or clay iron-stones and limonites, or hydrated oxides, resulting, with the exception of the ore of one deposit, which will be hereafter especially described, from the alteration and oxidation of the carbonates. They occur in stratified deposits at various geological horizons, not always forming connected strata, but still holding well-defined levels.

In the Waverly shales, toward the base of the series, there are numerous beds or layers of clay iron-stone kidneys, sometimes in considerable thickness. They are usually exposed along the banks and in the beds of the streams, where they have been left when the surrounding material has been washed away. Owing to their high specific gravity, the current has very little effect upon them, and they are thus concentrated in the beds of many of the streams in considerable quantities, so that, to the careless observer, they give the impression that there is a much larger quantity of the ore present in the hills than will be found on closer inspection. These ores have never, to the knowledge of the writer, been worked at any of the furnaces of this region. The reason of this, probably, is, that they are almost always found as hard blue carbonates, a

quality of ore which charcoal furnaces, the only kind as yet in this region, do not use if the limonite ores can possibly be obtained.

These ores are of such firm and close-grained structure that they yield to the oxidizing action of the air, and change to limonite very slowly, and with great difficulty. They are remarkable in this respect. Even when they are found in positions which show that they have been long exposed to the agencies which usually effect this change from carbonate to limonite, it is rare to find more than a thin coating of limonite on the surface of any specimen and along the lines of the weather cracks.

They are sufficiently rich in iron to be of value, and would doubtlessly be considerably used, were it not for the feature above noted. The deposits do not seem to be persistent over very large areas at the same level, but change position frequently. In addition to their irregularity, they commonly occur low down in the hills, where the slope is so steep that it would be impossible to bench for the ores to any depth; and they are usually too thin to pay for mining in any other way. The reason that they are not found near the tops of the hills is, that they lie towards the base of the series, and the Waverly does not extend far enough to the west to bring them to the top, where the slope over the ore would be gentle, and the thickness of overlying material slight, as these rocks soon disappear where the massive Conglomerate and limestone no longer protect them from erosion.

The thickness of these beds or layers of kidney ore ranges from four to eight inches. Were there furnaces in this region capable of using them, large quantities could be cheaply obtained and utilized, but it would not be judicious to rely upon them alone to supply any furnace; their proper use would be as a mixture to use with other ores.

THE LIMESTONE ORE.

The principal ore from which the iron has been manufactured, which has given to this region its reputation in the

markets of the country, is found resting upon the Sub-carboniferous or St. Louis limestone, and is known as the limestone ore. It is geologically the same ore as that already described in a previous report* as the "lower limestone" ore of Greenup and Carter counties.

The limonite of this bed, when at its best, is a heavy, dark red, friable ore, sometimes homogeneous and massive, and sometimes semi-concretionary. It often gives a red powder and streak, while containing its full proportion of combined water. The carbonate ore, from which the limonite is derived, is usually a dense, amorphous, close-grained ore, varying from light grey to dark brown in color.

The ore is found resting upon the surface of the limestone; not always in a regular layer or plate of uniform thickness, but in irregular "rolls," filling depressions in the surface of the limestone, between which the ore is often missing. These rolls are of much greater thickness than the average of the whole bed. They are often found several feet in thickness, while, when the ore occurs with anything like regularity, it is rare to find it averaging more than one foot. There is usually a considerable thickness of fine white shale and clay above the ore. This is a characteristic of the limestone ores in other parts of the State, which helps to distinguish them from other ores.

THEORY OF FORMATION.

In another report, already referred to, on the iron ores of Greenup, Boyd, and Carter counties, the theory of formation of these ores has been discussed, and to that report the reader is referred for a fuller statement than will be given here. It will be sufficient to state, here, the conclusions then reached, without repeating the different theories in regard to their formation, or the facts in favor of the conclusions below stated.

The carbonate or siderite is the original mineral of these ore beds, and from it the limonite, or the "red ore," as it is

*Report on the Iron Ores of Greenup, Boyd, and Carter counties, vol. I, part III, second series.

called, is derived by a process of oxidation and alteration through the agencies of the atmosphere and carbonated waters.

The depth to which the change from carbonate or siderite to limonite has been effected, varies with the character and thickness of the overlying material. Where this is thin, or where it is a porous sandstone, permeable to the atmosphere, the change will be found a long distance back from the outcrop, and sometimes entirely through the hill; but where a great thickness of impervious, dense rock overlies the ore, the limonite will be found only a short distance back from the outcrop, forming a narrow ring around the main body of carbonate ore, decreasing as the slope of the hill above it grows steeper. As the limonite ore is much the most valuable, owing to the fact that, in addition to its superior richness, it is more easily smelted and produces a better grade of iron, it will be seen that those deposits are of most value which are situated near the tops of the hills, where the ore has all been changed to limonite. The area covered by the ore bed, and the total quantity of the ore, when it is thus situated, is much less than when it lies lower down in the hills; but this is compensated by the superior quality of the ore.

The ore seems to have been formed by a segregation of the iron from the shales and clays above the limestone, subsequent to their deposition. Carbonated waters, percolating through these rocks, have taken the ferruginous material into solution in the form of the carbonate, carried it down and deposited it upon the face of the limestone, which, in its turn, was partially dissolved and carried away, thus producing the irregularities in its surface before referred to.

This theory of deposition, by segregation from the overlying rocks, accounts for the following characteristics of the ore, namely, the irregularity of thickness; the tendency to become suddenly calcareous, or to disappear altogether, giving place to a limestone: the comparative freedom from coarse silicious impurities, and the presence, above the ore, of the

thick beds of white clay, from which almost every trace of iron has been removed.

QUALITY OF THE ORE.

Unfortunately, at the time of the examination upon which this report is based, it was impossible to obtain as many thoroughly representative samples of the ore for analysis as were desired, owing to the fact that mining operations were being conducted at only one of the furnaces in this region. At the other furnaces the ore banks had nearly all fallen in soon after operations had been suspended, so that it was, in most cases, impossible to gain access to the ore in order to select average samples for analysis. The furnaces had also consumed almost entirely the stock of accumulated ore before going out of blast, so that it was impossible to obtain, at the stock piles, samples the location of which was known.

For this reason, the number of analyses given below is not nearly so large as desired, or as it would have been, had it been possible to get at the ore, in the banks, at many other places.

The same reason can be given why this report is not much fuller in details of measurements of the ore than it is. The furnace estates comprise but a very small proportion of the total area of this ore region. Except on these estates, no mining operations for ore have ever been conducted, and there is no means of knowing the exact thickness of the ore bed. The amount can only be estimated from the abundance, size, and persistency of the outcrop of the ore on the surface of the hill. This is only an imperfect method, and is subject to great inaccuracies; but it was the only one possible under the circumstances, as it is manifestly impracticable for the Geological Survey to undertake expensive explorations, which require digging. Neither time nor means was sufficient for such explorations.

The following analyses were made by Dr. Peter and Mr. Talbutt, from samples collected by the writer. They were all taken with a view to be as nearly average samples as pos-

sible; but they are not all equally so, for the reason that the amount of ore from which the sample was taken varied considerably. In some cases it was taken directly from the solid ore bed, while in others from the pile of ore lying on the bank:

	1	2	3	4	5	6	7	8	9
Iron peroxide. .	65.310	59.621	66.329	54.750	75.598	4.049	65.535	74.127	65.591
Iron carbonate	. . . .	. . . .	. . . .	. . . .	. . . .	76.491	. . .	. . . .	. . . .
Alumina	11.947	12.370	12.532	14 517	1.971	2.014	2.798	3.542	5.762
Lime carbonate. . .	.730	.500	a trace.	a trace.	.540	5.400	.450	.390	a trace.
Magnesia . . .	.140	.144	.173	.047	.258	.514	1.073	.461	.248
Phosphoric acid .	.825	.709	.709	.697	.601	.409	.537	.601	447
Sulphuric acid . .	a trace	a trace.	a trace.	a trace	a trace	.267	a trace.	a trace.	a trace.
Combined water	11 000	10.400	9.580	8 600	11.730	*1.426	9 800	11.270	11.000
Silica and insoluble silicates . .	9.580	15.830	9.720	20.830	8.910	9.330	20.480	9.580	16.230
Total	99.532	99.574	99.043	99.441	99.608	100.000	100.673	99.971	99.278
Metallic iron . . .	44.570	41.735	46.440	38 750	52.918	39.758	45.874	51.889	45.914
Phosphorus .	.360	.309	.309	.304	.262	.178	.234	.262	.195
Sulphur .	. .	. . . .	. . . .	. . . .	. . .	.107	. . .	. . .	. . . .

*And loss.

No. 1 is from the Pergam bank, Bath Furnace, Clear creek, Bath county.

No. 2 is from a bank near the head of Clear creek, Bath Furnace.

No. 3 is from the Richardson bank, Bath Furnace, Clear creek.

No. 4 is from the head of Ratcliffe branch of Beaver creek, Menifee county.

No. 5 is limonite ore, from the Tubbs bank, Estill Furnace, Estill county.

No. 6 is the carbonate ore, from the same bank as No. 5.

No. 7 is from Logan ridge, Estill Furnace.

No. 8 is from the Luster drift, Thacker Ridge, near Fitchburg, Estill county.

No. 9 is from the Horse Ridge banks, Cottage Furnace, Estill county.

With the exception of No. 6, all the above analyses are of the limonite ore of this bed.

It is probable that they all show the ore to be a little richer in iron than it really proves to be on actual working in the furnace This is due partly to the personal bias of the sam-

pler, which always acts in favor of the ore, no matter how careful he is, and partly to the fact that the sample is taken cleaner and freer from adhering dirt and clay than it is as it comes to the furnace scales.

It is stated that the average yield of the ore at Bath Furnace is forty per cent. The average in the four samples—Nos. 1 to 4, inclusive—from ore used at this furnace, is 42.77 per cent. of iron. The localities represented by these samples, however, are those which furnish the best ore to the furnace; so that it seems probable these analyses do not represent the ore as much better than it really is. They are all from within a radius of three miles. They are remarkable for the large and uniform per centage of alumina—an amount not heretofore found in any other ores of the State. The phosphorus is also remarkably uniform, although not excessively high for ore of this character. The absence of all except a trace of sulphur, save in the one sample of carbonate ore, is an excellent feature in these ores, and one reason why they are so highly valued. Another point of excellence is the comparatively small amount of silicious matter. This averages less than in any other series of ores in the State, as yet analyzed. This, in addition to the varied character of the other impurities of the ore, no one of which predominates very greatly, renders it easy to smelt, and tends to the production of a high grade of iron, as the silicon is not reduced with the iron, but combines with the other impurities, and passes off into the slag. For the same reason, the ore does not require a large amount of limestone for flux.

Another good quality of these ores, when limonites, is, that they are of an open, porous structure, so that they are easily permeable to the reducing gases of the furnace, which, therefore, act upon them readily. The carbonates are of a closer, denser structure, and are not so easily reduced. It is probable that much of the difficulty in working these ores satisfactorily, is due more to this peculiarity of their structure, than to any excess of impurities, although it is commonly attributed to the presence of sulphur.

DISTRIBUTION OF THE ORES.

For reasons before stated, it is impossible to give accurate and detailed statements of the exact thickness and quantity of the ore for every locality in this region. The most that can be done is to give its thickness at a few prominent places where it has been mined, and some notes as to its apparent relative abundance at other localities.

As stated in a former report,* this ore occurs in abundance along the outcrop of the Sub-carboniferous limestone, from near the Ohio river, in Greenup county, to the southern part of Carter county. Around Olive Hill, where last examined in detail, the ore is present in abundance, and seems to occur with more than usual regularity. From here, south to the Licking river, there have been no detailed examinations made. The region is wholly undeveloped—no mining operations nor pick and shovel prospecting ever having been attempted as yet. To the south of this, although no detailed examinations have been made, the ore has been seen in considerable quantity towards the head of Big Sinking creek, a branch of Little Sandy river, on the very head waters of Tygert's creek, and also on Christy's Fork of Triplett creek, a branch of Licking river.

There is in this vicinity a large amount of ore which will be opened to the world by the completion of the Lexington and Big Sandy Railroad; but, until that is accomplished, must remain wholly undeveloped.

Between Christy's Fork of Triplett creek and the Licking river, nothing is as yet known as to the occurrence of the ore, but there is no reason to doubt its existence there.

South of Licking river the ore occurs in abundance, and has been largely mined. On Caney creek, a stream but a few miles in length, large quantities have been mined for the supply of the Caney Furnace, which was situated upon that stream. It has not been in operation for a number of years. As a consequence, all the ore banks have fallen in, and noth-

*On the Iron Ores of Greenup, Boyd, and Carter counties, part III, vol. I, second series.

ing could be learned in regard to the thickness of the deposits.

On Clear creek, in Bath county, the deposits of the ore are extensive, and of excellent quality. It has been largely mined for the supply of the Bath Furnace, formerly called the Clear Creek Furnace. Several analyses of ore from this vicinity are given in the table. The ore was seen, at a number of openings, from six to sixteen inches in thickness. It is reported to occur frequently in "rolls" or pockets of two to three feet thick or more; but these are usually of limited extent, and soon exhausted. The ore varies so in thickness that it is impossible to give any accurate estimate as to its average; but it is probable that it would be slightly under twelve inches. It is usually found here resting under about five feet of white clay. At this distance above the ore there is usually found in the clay a thin coal streak; but it has never, to the writer's knowledge, been followed far enough back into the hill to be found solid. It is probable that this is the stain of a coal which, in other places, has been opened and found to be about fifteen feet above the limestone. The distance from the ore to the base of the Conglomerate in this vicinity is about sixty feet.

All of the branches of Clear creek cut through ore territory, as do a portion of the branches of Salt Lick creek, the stream into which Clear creek flows. Some of the branches of Salt Lick creek on the west extend beyond the ore field, while the main stream runs so near its edge that only a comparatively small area of ore is found along it.

Although mining operations have been conducted on Caney and Clear creeks at various times for nearly forty years past, yet the supply of available ore is by no means exhausted. Neither of the furnaces has been in constant operation. Caney Furnace was discontinued in 1848, and Bath or Clear Creek Furnace was idle from 1857 or 1858 to 1873. The consumption of ore has, therefore, been comparatively small, and the great mass of available limonite ore is almost untouched. So far the supply available by benching has been

ample, and drifting for the ore has been resorted to at but few banks, and in these cases only where the ore was of more than usual thickness and regularity, so that it could be mined cheaply. The Pergam bank, on Clear creek, is an instance of this kind.

Beaver creek, from its head to its mouth, may be said to run through ore territory. It is a long stream, and drains an ore area of many square miles; but it is at present wholly undeveloped. The ore outcrops in the surface clays are abundant, and in quantities sufficient to indicate that the ore is present in its full average thickness. The Bath Furnace draws a part of its ore supply from the country drained by some of the lower branches of Beaver creek. Leatherwood creek furnishes the larger portion of this. There are numbers of old ore banks on the lower part of Beaver creek, where ore was probably dug for the old forges which formerly were in operation in this vicinity—one on Beaver creek, and one on Licking river below the mouth of Beaver These banks have all fallen in, so that it was impossible to ascertain anything as to the thickness of the ore.

Higher up on Beaver creek ore was formerly mined for the Old Beaver Furnace, which is situated near the mouth of Myers' branch; but this has been discontinued for over forty years, so that the ore banks are in the same condition as those just described. If all accounts be true, however, the ore in this vicinity is more than usually abundant and trustworthy. As the furnace was only in operation ten or twelve years, the total amount of ore consumed was comparatively small—not enough to seriously affect the value of the ore lands, as the great body of ore is comparatively untouched.

The country drained by the branches of Beaver creek on the south has been more thoroughly examined by Mr. Crandall than by the writer, and to his report the reader is referred for details.

From here up to the head of Beaver creek the ore appears in about its average abundance in the outcrop. No mining operations have ever been undertaken here, and, in conse-

quence, nothing in detail is known in regard to the ore. On the head waters of the south and southeastern branches of Slate creek the ore is well developed. It has been discovered at many places recently, since the thorough prospecting which that region has been undergoing in the search for coal. This region holds a large amount of ore as yet wholly untouched. The same is true of the area drained principally by Indian and Gilladie creeks, which flow into Red river from the north, and Chimneytop creek from the south. All this region, as well as that drained by the branches of Slate creek, has been examined more thoroughly by Mr. Crandall than by the writer, and to his report the reader is referred for fuller statements than are given here. Further down Red river the branches from the south cut through an extensive and valuable ore field. Middle Fork of Red river and Cat creek are the principal streams from the south. They head in the dividing ridge between the Red and Kentucky rivers, but a little to the east of where this ridge has been most productive of iron ore in the past. No ore of any consequence has been dug on these streams, except at the heads of some of the most westerly branches, on the Estill Furnace property; but, so far as surface indications are to be depended upon, the undeveloped regions promise to be equally as rich as the developed.

On Red river and its smaller branches considerable ore was formerly mined and carried down the river to the old Red River Forge and Furnace; but these have long since ceased operations, and the ore banks have not been opened since. These ore banks extended out to the west, on isolated knobs, to within a mile or two of the old forge.

The main dividing ridge between the Red and Kentucky rivers, where it is drained by Hardwick's creek, and the most westerly branches of Cat creek and Middle Fork on the north, and by Miller's and Cow creeks on the south, holds the ore in great abundance. This locality has been more extensively worked than any other of the region. It is on this ridge that the Estill and Cottage Furnaces are situated, and from it and its spurs they have drawn their ore supply—one of them, Es-

till Furnace, for the last forty-five years. Nos. 5, 6, 7, and 9, in the table of analyses, are from this ridge. These samples were taken from piles of ore lying at the banks, as it was impossible to reach the ore bed, mining having been discontinued about a year before the time of examination, and the banks, in consequence, having fallen in. At many places in this vicinity all the ore which is available by benching has been exhausted, and in future resort must be had to drifting. For the reason just stated, the face of the ore was seen at few places, so that accurate measurements of thickness cannot be given. It is stated to average somewhat less than one foot in thickness, though often occurring locally much thicker. Ore has been extensively mined along this ridge for a distance of six or eight miles, extending from two to four miles on the east of Estill Furnace to about the same distance west of Cottage Furnace, where the ore disappears, the limestone at this distance coming so near to the surface that the ore has been all removed. The heavy Conglomerate cliffs do not overlie the ore until in the vicinity of Estill Furnace. The lower and thinner Conglomerate overlies it around Cottage Furnace, the distance between being about twenty feet. The limit of mining operations on the east of Estill Furnace is not due to the disappearance of the ore, but to the fact that it cannot be profitably wagoned a greater distance than from the banks at present farthest removed from the furnace. There is an apparent abundance of ore for a long distance to the east along the ridge.

On the spurs of this ridge extending to the south, between the branches of Miller's creek, are situated the numerous ore banks which furnished the supply for the furnaces of the Red River Iron Company, at Fitchburg, on Miller's creek. The best known and most productive localities are called Thacker Ridge and Kobb Mountain. Thacker Ridge lies on the east side of the branch of Miller's creek upon which Fitchburg is situated, and about one mile from that village, while Kobb Mountain is about three miles below, on the same side. The ore banks or benches extend continuously along the outcrop

of the ore from one of these localities to the other. The ore has not only been benched for very deeply, but many drifts have also been run. It does not differ materially in quality or thickness from that on the main ridge at Estill Furnace. It was seen at a few places from eight to twelve inches in thickness; but many local "pockets" have been found in the drifts which reached three feet or more. Although some few minor spurs of Thacker Ridge have been nearly exhausted of their ore, yet there is in this vicinity a quantity of ore amply sufficient to meet all probable demands of the furnaces for a long time to come; for, in addition to the large amount yet remaining in the ridges east of Fitchburg, the ore in the ridge to the west is as yet intact, no mining of any consequence having been attempted there.

South and east of this vicinity, lying within the drainage of the main branches of Miller's creek, there is an extensive ore field, which is wholly undeveloped. It extends, on an average, from six to eight miles to the east. Ore will be found much further to the east; but beyond that distance the limestone is so near the drainage level that the outcrop line of the ore is limited, and the hills rise so steeply above that the amount available by benching is small. For the same reason, the amount of limonite, in proportion to the carbonate ore of the bed, is small, as the great thickness of overlying material prevents the alteration of the ore from carbonate to limonite.

The branches of Miller's creek draining this region head in the Conglomerate, and cut their channels in that rock and the shales below, for several miles, before they reach the limestone; so that the ore does not extend above the drainage level to the heads of these streams.

So far as it was possible to ascertain by merely surface examinations, this region seems to contain the ore in almost or quite as great abundance as the developed localities further north and west. It affords fine locations for the erection of new furnaces, as, in addition to the ore, the timber supply is good, the original unbroken forest still covering the greater part of the area.

Along the Kentucky river, on the north side, the ore is found at its proper level, in greater or less abundance, as far up as Contrary creek, a short distance above which the limestone passes beneath the drainage. On Contrary creek, however, and for some little distance below, surface indications do not promise much ore; but the circumstances are most unfavorable for its outcropping, as the top of the limestone is here almost to the drainage, and the hills rise steeply above. Further down the river, on the Willow Shoals branch, and the river hills above Old Landing, the ore is found in abundant outcrop and of excellent quality. On the Willow Shoals branch there are other ores lying in the shales above the limestone, of excellent quality, but apparently thin. Nothing is known of their horizontal extent.

South of the Kentucky river the limestone ore has not been mined, and its limits and distribution are almost unknown. Time did not admit of extending the examinations on this side to any distance back from the river. The geological features on this side are similar to those on the north, and there is no reason why the ore will not be found in as great abundance, when it comes to be sought for at its proper level. Outcrops of the ore were found on Buck, Ross, Station, Camp, and Doe creeks, and it is reported to occur abundantly on Sturgeon creek. As the limestone does not pass below drainage for some distance above the mouth of Sturgeon creek, it is not improbable this statement is correct, although the outcrops will probably be found more abundantly on the branches from the west, where the limestone is higher than on the main stream.

On all of the streams mentioned, the ore was found within a few miles of the river. In some places the outcrops were abundant, and at others scarce. There was no apparent difference in the quantity and distribution of the ore from a similar area on the north side of the river. The ore seems just as abundant, and of as good quality, as in the undeveloped localities on the other side.

Within the limits named, on this side of the river, there are many square miles of ore territory. The timber is almost unbroken, and exists close to the river in quantity sufficient to supply a number of blast furnaces for many years to come.

THE CLINTON ORE.

In Bath county, on the waters of Slate creek, about five miles south of Owingsville, there is a deposit of ore of a character different from any yet described. Neither geologically nor geographically does it strictly belong among the ores of the Red River Iron region; but as it is a somewhat isolated deposit, situated nearer to this region than any other, and is connected with it in certain economical relations, it will be described here.

The deposit is known as the Old Slate Furnace ore bank. It lies on top of two or three hills, about two hundred feet above Slate creek. It is associated with the yellow Silurian limestone of the Clinton period. It is, in fact, geologically, the same ore as that variously known as the Clinton, fossil, or dyestone ore, which is found along the "great valley" of the Allegheny Mountains from New York to Alabama, and is characteristic of the Clinton period at many other places.

The ore is a limonite, very oölitic and fossiliferous. It bears evidence of having been originally a hematite, similar to the Clinton ore as usually found; but it has lain so long exposed to the action of air and water, protected only by a thin covering of the soil, that it has absorbed water and been converted into limonite. It is a soft, earthy, inferior looking ore; but, as shown by analyses, is much richer than commonly supposed.

It is apparently a stratified deposit, but of comparatively limited extent horizontally. Its maximum thickness is stated at fifteen feet, which is said to be the thickness revealed by a test pit sunk some years since. On one end of the Block House hill the ore is exposed frequently from ten to twelve feet thick. The principal banks are known as the "Block House" bank and "Howard Hill."

The area covered by the ore on these two hills, and two or three smaller isolated knobs, as determined by the Survey of Mr. C. Schenk, Topographical Assistant of the Survey, is 1,943,870 square feet, or 46.9 acres. The average thickness of the ore over the whole deposit is difficult to estimate, as full exposures are rare, except on one end of the Block House bank. It would probably be considerably within the limit to place the average thickness of the whole deposit at ten feet; but for the sake of perfect safety in the following estimate of the quantity of ore in this deposit, it will be placed at eight feet. The determination of the specific gravity of two samples by Mr. Talbutt gave respectively 3.405 and 3.47. With a specific gravity of 3.4, an average thickness of eight feet, and an area of 46.9 acres, the total amount of ore will be 1,475,259 gross tons. With an average thickness of ten feet the amount will be 1,844,073 gross tons.

It is believed that the above estimate is far within the limits of the quantity actually present, as a part of the deposit is nearly twice as thick as the estimated average, and there are few, if any, places where the ore seems to be below the estimate. This ore differs very materially from the Clinton, or dyestone ore, as usually found in other States, in that it seems to be of limited horizontal range. The elevations in the vicinity, besides the hills just named, which are high enough to hold the ore if it were widely extended, are few, and in them, if the ore be present at all, it is so thin that it gives scarcely any outcrop on the surface. Further east, where the dip has brought the rocks down, the ore seems to be wanting. The place of the ore is apparently about forty feet below the top of the yellow Silurian limestone.

At one or two localities within a few miles of these banks, an ore has been observed at the junction of the Devonian shale and the underlying limestone. This ore differs widely in its structure and composition from the Clinton ore. It is a very silicious, porous limonite, and apparently is of recent formation, deposited by the waters of chalybeate springs. At one

of the places where this ore was found the spring is still flowing.

The following is an analysis of a sample of this variety of ore, from a hill called Pilot Knob, near the line of the Lexington and Big Sandy Railroad, in Bath county:

ANALYSIS BY DR. PETER AND MR. TALBUTT.

Iron peroxide	47.321
Alumina	5.418
Lime carbonate	.690
Magnesia	.079
Phosphoric acid	.161
Sulphuric acid	.376
Silica and insoluble silicates	33.330
Combined water	12.050
Total	99.425
Metallic iron	33.125
Phosphorus	.070
Sulphur	.150
Silica	27.600

At Daniel Blevins', a few miles east of this place, an ore was found occupying a similar position, but of somewhat better quality.

QUALITY OF THE CLINTON ORE.

The chemical composition of the ore from the Old Slate Furnace banks is shown by the following analyses by Dr. Peter and Mr. Talbutt, from samples selected by the writer. The samples were intended to be as fairly representative as possible:

	1	2	3
Iron peroxide	76.077	69.728	70.060
Alumina	2.592	8.642	4.540
Manganese	.430	. .	. . . . .
Lime carbonate	.130	.170	.040
Magnesia	.281	.045	.021
Phosphoric acid	.731	1.154	1.620
Sulphuric acid	.030	.134	.031
Silica and insoluble silicates	8.180	7.930	11.530
Combined water	12.300	12.650	12.300
Total	100.751	100.453	100.142
Metallic iron	53.254	48.809	49.042
Phosphorus	.319	.504	.707
Sulphur	.011	.053	.012

No. 1 is from the Block House hill; sample from all parts of the ore exposed.

No. 2 is from same locality; sample from the upper part of bed.

No. 3 is from the Howard hill.

It will be seen by the above analyses that the ore is much richer in iron than is generally supposed. The per centage of phosphorus is also large, as was indicated by the character of the iron made from the ore.

The country in the vicinity of the ore is pretty generally cleared of its timber, so that it is doubtful if this ore will be again used in this vicinity for the manufacture of charcoal iron; but it will in the future be largely shipped to furnaces using stone-coal, in the Hanging Rock region and other localities, where it will be used to mix with the coal-measure ores. The ore is but a short distance from the located line of the Lexington and Big Sandy Railroad, and would furnish a large amount of freight to that road upon its completion. It will prove valuable to mix with the limestone ore of the Red River region, and will be extensively used for that purpose when some means of cheap transportation can be had.

II. THE IRON MANUFACTURE.

The iron manufacture of this region is the oldest in the State of Kentucky, if not in the West.

As yet it has been confined to the production of cold-blast charcoal iron, which is used mostly for the manufacture of car-wheels, for which purpose it is unsurpassed by any iron in the country. It is of great strength, and at the same time chills readily. It has commanded a market all through the West, where it ranks with the best known and most celebrated brands of car-wheel iron in the country.

The first furnace in Kentucky was situated on Slate creek, in Bath county, and was called the Slate Furnace. It does not properly belong to the Red River Iron region, as it used different ore, produced a different grade of iron, and was located some distance from the other furnaces; but as it was the pioneer furnace in the State, and the only one in this vicinity, it will be described here.

According to one authority, it was built in 1791 by Thos. Dye Owings; according to another, it was built in the same year by Jno. C. Owings. It continued in operation until 1838. It used the Clinton ore from the already described banks, which were two miles south of the furnace. The blast machinery was driven by water-power, which was often insufficient to give sufficient blast to keep the furnace working regularly. There were two forges in the vicinity which made bar iron from the pig iron of the furnace.

Mr. Joshua Ewing, who was in charge of the furnace for the last ten years of its operation, states that its production was about three tons per day, using nearly or quite three tons of ore to the ton of iron.

The working of the furnace was very wasteful, as is shown by the character of the slag produced, and the fact that, so large an amount of iron was lost in the slag as scrap, that after the furnace ceased operations, the slag heap was worked over, the slag broken up, and a large amount of scrap iron obtained from it. This excessive waste of iron accounts for the difference between the yield as reported and the per centage of iron in the ore as shown by the analyses. The iron made at this furnace had a poor reputation as regards strength, but was very hard. This was due to the large

amount of phosphorus which it contained, as is shown by the following analysis of a piece of scrap iron from Slate Furnace, by Dr. Peter and Mr. Talbutt:

Iron	92.056
Graphitic carbon	3.640
Combined carbon	.310
Silicon	1.760
Slag	.100
Calcium	.116
Phosphorus	1.080
Sulphur	.218
Total	99.280

This iron is not of as good quality as that made from the limestone ore.

The next furnace established, and the first in the Red River region proper, was on Red river, in the large bend above the mouth of Hardwick's creek, in Estill county. It was built in 1806 or 1808 by Wm. Smith. There was also, at the same place, a forge running four bloomery fires, which was built a year or two previous to the furnace. The supply of ore was obtained from the hills on both sides of the river, some distance above the furnace, and boated down the river in flat-boats to the dam just above the furnace. This dam backed the water sufficiently to render the river navigable for small boats. It also furnished the water-power to drive the blast machinery of the furnace.

This furnace was in operation until about 1830. There was subsequently a rolling-mill erected at this same place, which continued in operation till about 1860, when it was removed, owing to the excessive cost of coal, which was brought down the Kentucky river and wagoned across.

It is stated that the furnace stack was first constructed of the Devonian black shale, which is the prevailing rock in the vicinity. This shale contains a considerable amount of bituminous matter, which, when the furnace became heated, took fire and burned all through the stack, with the result that the rock was so softened and cracked that the furnace had to be rebuilt with more solid material.

The next furnace erected was Beaver Furnace, on Beaver creek, Menifee county. It was built in 1819, by John T. Mason and four others, whose names could not be clearly deciphered from the inscription on the old stack.

This furnace, like the other two, was driven by water-power. There were two forges near, one on Beaver creek below the furnace, and one on Licking river below the mouth of Beaver creek.

The furnace continued in operation until about 1830. It used the limestone ore from the vicinity.

These three furnaces were built and running several years before the erection of the first furnace in the Hanging Rock iron region, which was built in 1822. They, as well as Caney Furnace, on Caney creek, which was built in 1838, by Mr. Joshua Ewing, and went out of blast in 1848, have all been abandoned, from one cause or another; usually either excessive cost of transportation or exhaustion of timber supply.

The active furnaces of this region are five; they are as follows:

Name of Furnace.	When built.
Estill	1830.
Bath.	1839.
Cottage	1856.
Red river, two stacks	1869.

Bath Furnace, as already stated, is situated on Clear creek, in Bath county. Estill and Cottage Furnaces are on the ridge between the waters of the Red and Kentucky rivers, while the two stacks of the Red River Company are situated on Miller's creek, about six miles from the Kentucky river. All of these are in Estill county. The machinery of all these is driven by steam.

With the exception of the two furnaces of the Red River Iron Company, which will be described hereafter, these furnaces are all of the old type, with heavy sandstone stacks, in the form of a truncated pyramid.

The principal internal dimensions of these furnaces are shown by the following table:

DIMENSIONS OF BLAST FURNACES IN THE RED RIVER IRON REGION.

	Bath.	Cottage.	Estill.	Red River, 2 stacks.
Height	40′	38′	34′	50
Diameter of bosh	10′ 6″	10′ 6″	10′	12′ 6″
Batter or slope of bosh	58°	55°	55°	55°
Diameter of throat	3′ 6″	3′ 2″	4′	7′
Height of hearth	6′	6′	6′	6′ 6″
Diameter at top of hearth	3′ 8″	3′ 4″	3′ 2″	4′ 4″
Diameter at bottom of hearth	3′ 3″	2′ 8″	2′ 6″	3′ 9″
Number of tuyeres	2	2	1	3′
Diameter of tuyeres	3½″	3½″	3″	4″
Height of tuyere above bottom of hearth	2′ 7″	2′ 8″	2′ 6″	3′ 6″
Number of boilers	2	2	2	4
Diameter of boilers	2′ 10″	3′	3′	3′
Length of boilers	50′	46′	45′	45′
Number of blast cylinders	2	2	1	1
Diameter of blast cylinders	2′ 10″	3′ 4″	3′ 4″	5′
Stroke of blast cylinders	6′	one 6′, one 5′	5′	4′
Diameter of steam cylinder	1′ 2″	1′ 4½″	1′ 4″	2′
Stroke of steam cylinder	6′	6′	5	4′

These furnaces all use the limestone ore, working with cold-blast for the production of a car-wheel iron. The Red River Furnaces are the only ones which have a hot-blast oven connected with them, and this has not been used since the first year or two of the furnace operations.

The dimensions and arrangement of the two stacks of the Red River Iron Company, at Fitchburg, on Miller's creek, are shown by the accompanying plate. They represent the first attempt at improved furnace construction in this region. They are twin stacks built in a solid rectangular mass of masonry, forty by sixty feet base, and fifty feet high. They worked with closed tops, originally with the bell and hopper apparatus; but this was finally removed, and a thimble-charging apparatus substituted. The hot-blast oven is on top of the stack. The gases are carried down twenty-two feet, through a gas main twenty-six by thirty-six inches in cross-section, to the boilers, of which there are eight, in four nests of two each.

The engines are modern, vertical, direct acting, with steam cylinder twenty-four inches diameter and four feet stroke; blast cylinder five feet diameter by four feet stroke. Everything in connection with the furnaces is constructed in the most thorough and substantial manner. The cost of the furnaces alone, without machinery, was over one hundred thousand dollars, while the cost of the machinery and fittings brought the total cost of the two stacks to nearly one hundred and sixty thousand dollars.

The metallurgical success of these furnaces has been all that was expected; the iron produced was of the very best quality, and commanded the highest prices, and the furnaces produced a large yield on a moderate consumption of charcoal. One stack has made as much as 480 tons of cold-blast iron in one month, on a consumption of 166 bushels of charcoal to the ton of iron; and during one week it made 128½ tons, using only 155 bushels of charcoal per ton. This, however, was exceptional working. The average consumption of charcoal was somewhat greater, and the production of iron less. The following table shows the average yield of the roasted ore, the consumption of charcoal per ton of iron, and the number of years during which the furnaces were in operation, from which these results were averaged. This table includes the two stacks which were respectively named Chandler and Blackstone, and also Estill Furnace, which is the property of the same company:

RED RIVER IRON COMPANY'S FURNACES.

Name of Furnace.	No. years from which averaged.	Average yield of roasted ore, per cent.	Average consumption of charcoal per ton of iron, bushels.
Chandler	4	44.2	231
Blackstone	5	45.1	204
Estill	5	46.4	215

It was impossible to obtain the figures for the yield of the raw ore with any accuracy. It is stated, however, by those connected with the furnace, to be thirty-three and one third per cent. One series of figures, obtained with regard to the

yield from the raw ore at Estill Furnace, gave the average for five years as 33.03 per cent.; but there was some obscurity in regard to some of the items which cast a shade of doubt over their accuracy. The returns for the yield of roasted ore are probably accurate, as they were taken from the daily blast report book.

It is to be regretted that it was impossible to obtain similar returns from the other furnaces of this region. The average yield of the roasted ore at Bath Furnace, for one period of sixteen weeks, was 51.7 per cent. No returns of charcoal consumption were obtained from this furnace.

None of the furnaces of this region are at present in operation, or have been since 1874, with the exception of Bath Furnace, which made a short campaign in 1875, during which less than fifty tons of iron were made.

This is due to the extremely depressed condition of the iron trade all over the country, the prices of pig iron ruling so low at present that it cannot be manufactured in this region and brought into market at a profit. This is owing more to the excessive cost of transportation to market than to the original cost of the iron at the furnaces. Iron can be produced at these furnaces for much less than at many other localities which are nearer to market, as ore, charcoal, and labor are all cheap; but the facilities for transportation are so poor, that it costs from seven to ten dollars per ton to carry the iron from the furnace to market at Louisville or Cincinnati. This tax is so great that, at present prices, it either entirely consumes the profits, or leaves the margin so small that it is not worth the risk.

The furnaces of the Red River Company, on Miller's creek, shipped their iron in flat-boats down the Kentucky river at time of high water, while the other furnaces usually hauled their iron to the railroad, in every case a distance of over twenty miles. Were there railroad or slack-water transportation within a few miles of each furnace, it would be profitable to make iron in this region, even at the present extremely low prices; but the necessity for wagoning it such great dis-

tances, or of awaiting the uncertain rises of the Kentucky river, and the danger of navigation when the rises come, render the cost of transportation entirely too great.

The construction of any of the projected railroads through this part of Eastern Kentucky, or the extension of the system of slack-water navigation on the Kentucky river to the mouth of the Three Forks, will give the desired facilities to a large part of this region, and be followed by the erection of new furnaces where heretofore the ores have lain undeveloped, owing to the difficulty and cost of getting the iron to market.

As a commercial enterprise, the furnaces of the Red River Iron Company have not been successful. From a metallurgical stand-point, the furnaces have been all that could be expected; but the property of which they form a part, and in which they are the chief producing apparatus, has not been profitable to its owners.

After an investment of about one and a half millions of dollars in lands, furnaces, buildings, dwelling-houses, tram-ways, roads, and other improvements, the company has failed to pay the interest on its bonded debt, and the property has passed into other hands, leaving a clear loss of over a million of dollars to the original stockholders.

These stockholders were mostly capitalists from outside the State, and the failure of an enterprise in which they had invested so largely, and which had been so liberally established, cannot fail to greatly injure the reputation of this region as an iron-producing district, and seriously retard its development in the future, by preventing the investment of capital from abroad, as it will inevitably be charged to the incapacity of the region to sustain an extensive iron industry, unless it can be shown that other causes should be charged with the failure.

That this is the case there can be little doubt. In the first place, it can be said that the furnaces were not adapted to the region, nor for the purpose of making charcoal iron. There was no difficulty, so far as the mere working of the furnace was concerned; but the capital mistake was in erecting two

such large and unnecessarily expensive furnaces, away from any line of transportation, with the expectation that they would both be supplied with ore and charcoal from the immediate vicinity The furnaces each require, to keep them in operation, about double the amounts of ore and charcoal that the older and smaller furnaces use. The large furnaces will each produce, when working anything like full time, from three thousand to four thousand tons of iron per annum. To make this amount of iron will annually strip about four hundred acres of land of its timber, or eight hundred acres for the two furnaces. At this rate of consumption, the land around the furnaces would be cleared so rapidly that, in a few years, the limit of economical haulage of charcoal would be reached. The same would occur with the ore supply. The ore deposits of this region are of such a character that, so long as they are used by charcoal furnaces, which work exclusively the limonite, which is found only near the outcrop, a very large area of the ore bed will be required to supply the demands of a furnace. Only a comparatively small amount of ore is usually obtained at one locality; so that, when a large production is required, the exhaustion of the limonite in any given region is rapid; the workings are removed farther and farther from the furnace, and the cost of hauling the ore increases proportionately. Where the ore is obtained by drifting, instead of benching, this does not take place so rapidly; but, as a general rule, not a great deal of limonite is obtainable in this way, as the ore changes to carbonate on following it under ground, where the overlying rock is thick and impervious. There are many localities near the western edge of this ore field where the thickness of rock over the ore is slight, and the whole ore bed is changed to limonite; but, where this is the case, the total area of the ore is small, as it lies so near the summit of the hill.

The style of furnace adapted to the economic necessities of this region, is either a small cheap furnace, which can use all the ore and timber within easy hauling distance, and then be abandoned after twenty or thirty years without great loss,

or a more expensive, larger furnace, intended to be permanent, located upon some line of transportation, either railroad or river, by which supplies of ore and fuel can be cheaply brought to it from a distance, after that within hauling distance has been exhausted.

With a reasonable cost for transportation of iron to market, a large number of furnaces of either or both of these classes can be sustained in this region, and will produce iron so cheaply that it can be manufactured at a profit in almost any probable state of the market. These conditions apply to the charcoal iron manufacture. With reference to the manufacture of iron with stone-coal or coke, an industry which has not been attempted here as yet, but which is destined at some not far future day to become important, it may be said that the location of furnaces for this purpose, on some line of transportation, is absolutely essential, as the coal will have to be brought from further back in the eastern coal field; for, with a few exceptions, the Sub-conglomerate coals are not at their best development where the ore is found at its best. An additional reason is, that stone-coal iron, being a lower-priced product, will not bear the expense of transportation that charcoal iron can.

The furnaces of the Red River Iron Company are fitted to none of the conditions best adapted to economical and profitable working in this region. They are large, expensively built furnaces, furnished in the most complete and substantial manner, and everything about them showing that they were built to be permanent. They are, however, located six miles from the Kentucky river, to which the iron had to be hauled for shipment. They are, therefore, dependent upon the immediate vicinity for their supply of ore and fuel. Experience has proved that it is inadequate to supply, at reasonable rates, the amount required to keep both furnaces in full operation for the most of the time. The two furnaces require, to keep them in constant operation, about four times the amount of ore and fuel which any one of the older furnaces of this region use.

The records of the two furnaces show that, with the exception of the year 1871, which was the first year after both were fairly started, and when they together produced between seven and eight thousand tons of iron, they have never both been worked to anything approaching their full capacity; and this, too, during part of the time when iron commanded the highest price it has reached for years, and when, therefore, every inducement was offered managers to urge the production of their furnaces to the utmost limit. This proves the original statement, that, to supply two such large furnaces at profitable rates, is beyond the capacity of the region immediately surrounding and within easy hauling distance.

In addition to the mistake in the location and size of the furnaces, they were unnecessarily expensive. The same may be said of all the improvements made by the company. The number and style of buildings, and the investments for roads, tram-ways, &c., were somewhat extravagant. The buildings of one sort and another cost considerably over two hundred thousand dollars, while the cost of roads, tram-ways, inclines, etc., was nearly one hundred thousand. All of these items, added probably to some considerable extravagancies, or at least the lack of economy in the management, combined to make the total investment of capital in the enterprise much greater than could reasonably be expected to pay a good interest, under the most favorable circumstances.

As a further proof of the above statements in regard to these furnaces, it may be stated that Estill Furnace, which, with all its buildings and improvements, cost not more than ten or fifteen per cent. of the total cost of the large furnaces and their improvements, produced, in the five years from 1870 to 1874, inclusive, nearly one half as much iron as was made by the two large furnaces, when, had they been worked up to their capacity, they could readily have made four times as much as the smaller furnace, with its imperfect machinery.

When improved transportation facilities are afforded this region, so that iron can be shipped to market at a reasonable price, these furnaces will be profitably operated, for a portion

of the year at least, with ore and charcoal obtained from the immediate vicinity; but they will be best developed by a railroad which shall bring to them ore and fuel from a distance.

This whole region has a great future before it as an iron manufacturing district. It is capable of sustaining many times the present number of furnaces; but its development must depend upon, and be determined by, new lines of transportation. Until means of transportation are improved, it is useless to look for any great development. The character of the ore deposits must also be considered in constructing furnaces in this region, and only furnaces adapted to them be erected. The experience of the Red River Iron Company proves conclusively that this pattern of furnace is not adapted to this region, unless the furnaces be situated on some line of transportation where ore and coal can be brought from a distance.

QUALITY OF IRON.

The following analyses show the chemical composition of a number of samples of iron from this region:

ANALYSES OF COLD-BLAST CHARCOAL PIG IRONS FROM THE RED RIVER IRON REGION, BY DR. R. PETER AND MR. J. H. TALBUTT.

	No. 1 Cottage.	No. 1 Estill.	No. 1 Red River	No. 3 Red River	No. 5 Red River	No. 1 Bath.	No. 2 Bath.	No. 3 Bath.	No. 4 Bath.
Iron	93 106	92.582	94.174	93.728	93.963	92.631	91.924	93.472	93.004
Graphitic carbon .	3.860	3.500	3.340	3.520	2.000	3.840	3.440	3.100	2.700
Combined carbon.	.590	1.200	1.110	.780	2.550	.710	1.060	1.510	1.410
Silicon	.914	.960	.447	1.202	.363	1.520	1.319	.652	1.007
Slag	.160	.360	.360	.360	.320	.100	.260	1.600	.260
Phosphorus. . . .	.527	.444	.402	.290	.338	.363	.220	.290	.26a
Sulphur . . .	.011	.066	.182	.081	.104	.278	.107	.121	.172
Total . .	99.168	99.112	100.015	99.961	99.638	100.180	98.330	100.745	98.815

Some of the above analyses were more complete than as given here. For the complete analyses, see the report of Dr. Peter.

The excellent quality of this iron is due to the comparatively small per centages of phosphorus and silicon. A comparison of these analyses with those of Hanging Rock hot-blast pig irons, published in volume I, second series, Kentucky Geological Reports, shows a marked difference in the

per centages of these ingredients in favor of the Red River irons. When the Red River ores come to be worked with hot-blast, it is probable that the per centage of silicon will be increased; but the phosphorus will remain about the same.

PRODUCTION OF IRON.

The following table shows the production of iron in this region for the years 1870 to 1874, inclusive. In 1875, there was no iron made at any of the furnaces, with the exception of one lot of forty-eight tons at Bath Furnace.

These figures were obtained from the furnace books for all the furnaces, except Cottage. The returns for that furnace are probably accurate, as they were obtained from the former proprietors:

Name of Furnace.		1870.	1871.	1872.	1873.	1874.
Bath		not in blast	not in blast	not in blast	795	1339
Cottage		*1000	1850	1900	1950	not in blast
Red River Iron Company's Furnaces.	Estill	1167	1880	1967	1375	388
	Chandler	2109	3855	2564	613	not in blast
	Blackstone	772	3529	289	1057	1284
Total		5050	11114	6720	5790	3011

* Estimated.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

REPORT

ON THE

IRON ORES

IN THE

VICINITY OF CUMBERLAND GAP.

BY P. N. MOORE.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

ON THE IRON ORES IN THE VICINITY OF CUMBERLAND GAP.

The iron ores of economical importance in this region lie on the southeast of Cumberland Mountain, usually in the range of foot-hills known as the Poor Valley Ridge, which is almost always seen at the base of the mountain. Occasionally, this ridge disappears, and we find the ores on the flank of the mountain proper, near its base; but their occurrence in this position is exceptional.

The ores are, consequently, in Virginia and Tennessee; but as they occur so close to the Kentucky line, and are so intimately connected with Kentucky interests, in that they cannot be fully developed without the use of Kentucky fuels, an examination was made of them for a few miles up and down the mountain, from Cumberland Gap, to ascertain something as to their method of occurrence, quantity and quality, and to determine the capabilities of the region to sustain an iron-manufacturing industry.

The manufacture of iron from these ores with charcoal fuel has been, for a long time, carried on in this vicinity in a small way, at a number of places; both pig iron and blooms having been produced. It is, however, upon coal as a fuel that the permanent iron industry must be founded, and the coal which will, in the future, smelt the ores along the mountain for a considerable distance below, and for a still greater distance above Cumberland Gap, must come from Kentucky. There is no coal to the southeast in either Tennessee or Virginia, and Cumberland Gap affords the most feasible passage by railroad through the mountain, from the ore to the great Kentucky coal field.

Such being the case, these ores become of almost as much importance to Kentucky as to the States in which they are

situated, especially when we consider that their development is dependent largely upon a Kentucky railroad enterprise to give them access to market. Either of the projected railroads through Kentucky to Cumberland Gap, will find in the transportation of these ores, and of the iron made from them, one of the most important sources of revenue.

The ores of this region are stratified hematites, belonging to the Clinton Group of the Silurian formation, a group which has been designated as the Dyestone Group by Prof. Safford, in his report on the geology of Tennessee. The ore is variously known as the Dyestone or Fossil ore, and sometimes simply as the Red ore. It is called the Dyestone ore, from the fact that it is sometimes used for dyeing purposes by the residents of the region where it is found.

The rocks with which it is associated are usually shales, sometimes calcareous, which occasionally pass into thin-bedded sandstones. There are also occasional interstratified thin beds of limestone, which increase in frequency toward the lower part of the series, and below the ores.

The thickness of the group in Tennessee, as stated by Prof. Safford, varies from two hundred to three hundred feet. In this vicinity it is usually thicker, ranging from three hundred to five hundred feet. These rocks pass almost imperceptibly into the Medina sandstone below. This sandstone is here thin-bedded, and less marked in every way than it is further southeast, where it is the massive determining rock of Clinch Mountain; but it is still heavy enough to form, with the lower portion of the Clinton beds, the Poor Valley Ridge, or foot-hill range of Cumberland Mountain. The "Poor Valley," between the foot-hill and the mountain, is excavated in the thin bedded, soft, and easily eroded Clinton rocks, and it is to their silicious nature, and the soil resulting from them, that the infertility of the valley is due. The Devonian shale and the Waverly also help in the formation of the valley to a certain extent, but the Clinton shales are particularly the valley rocks. Usually the shale above the ore occurs in the valley, and the upper ore (of the three to be hereafter described),

with a thin but hard sandstone immediately above it, is the highest and crest-forming rock of the Poor Valley Ridge.

As already stated, the ore occurs in beds or layers, interstratified with shales and limestones. It differs much in quality in the different beds; but when at its best, is an oölitic, greasy-feeling, fossiliferous hematite, formed at places almost entirely of fragments of crinoid stems. Other fossils are numerous, but by no means reach anything like the proportion of the crinoidal remains.

The ore has not been studied in sufficient detail over a large area, where it has been opened in depth, and the overlying rocks are fully exposed, to enable the writer to form a theory of its formation satisfactory in every respect; but the structure of the ore, in most cases, indicates, beyond reasonable doubt, that it was originally a bed of fossiliferous limestone. The original limestone has been dissolved and removed by the solutions which brought the iron and deposited it in the form and place of the limestone. The iron has probably been derived from the rocks above, and has been gradually removed by a process of leaching.

This ore is by no means a local deposit. It is characteristic of the rocks of this period, from New York to Alabama, and it is also found in the same formation in Wisconsin, of a quality that can hardly be distinguished from the New York or Tennessee ore. This marked uniformity of quality and position of the ore show that the waters, at the time of the deposition of these rocks, must have been very uniformly charged with iron over an area hundreds of square miles in extent. There is no similar formation in which iron ore is distributed with anything like so great uniformity, or of which it is so characteristic. Other ores are found usually connected with rocks of a particular formation, but they are by no means coextensive with that formation; they are, on the contrary, "pockety" and erratic. This, however, both in quality and position, maintains its identity along the parallel mountains of the Appalachian series for hundreds of miles. In the aggregate, therefore, it presents a mass of ore which is

practically inexhaustible, and is unequaled by any other deposit in the country.

In New York and Pennsylvania ore of this age is largely worked for the supply of blast furnaces; but south of those States it is almost untouched, although in Virginia and Tennessee a number of small charcoal furnaces and forges have been using it for many years past. Their consumption is so small that, in comparison with the vast amount remaining, what ore they have used is too small for notice.

There are usually found in the region under consideration three beds of ore. These have been found to extend with considerable regularity for five or six miles each side of Cumberland Gap. Whether they are persistent at a greater distance above the Gap than this is not yet known. Ore is found in good thickness at many places above; but the sections taken have not been detailed enough to prove the existence of more than one bed, although there is no reason to doubt that the others will be found when properly sought for. Below Cumberland Gap, at Speedwell Furnace, two ores have been worked, apparently corresponding to the middle and upper of the three above mentioned, with the distance between them considerably increased.

The positions and relative distances apart of the three ores are shown in the sections of the accompanying plate. These sections were all taken within a few miles of Cumberland Gap, and the most of them within one mile and a half. It will be seen from them that the ores are sometimes found at the foot of the mountain proper, and sometimes in the Poor Valley Ridge.

They are of the most value when they occur in the ridge, for the reason that there is then a larger amount of the ore above drainage level, where it can be much more easily and cheaply mined. It is also probable that, at a certain depth below the drainage level, the soft fossiliferous ore becomes hard, calcareous, and poor in iron; in other words, that it approaches the condition of the original limestone, and is no longer profitable to work in the furnace. This opinion is

not founded upon observations in this immediate region, for mining has not yet been carried deep enough to ascertain the fact; but it is based upon reports of mining operations upon the same ores at other and widely separated places. When the ore occurs in the Poor Valley Ridge, it dips nearly with the slope of the ridge on the mountain side, so that there is a large amount of it at a uniformly small depth below the surface; while, when it is in the mountain, it dips directly back from the surface; and even if it does not change its character, and become lean, it will soon become difficult and expensive to mine.

It will be seen from the accompanying sections, that the distance between the upper and middle ores varies from seventy to one hundred and five feet. The distance between the middle and lower ores is from two hundred to two hundred and fifteen feet.

The upper ore is the most valuable of the three in this region. It is soft, very fossiliferous, and much richer in iron than the middle ore, although it is not nearly so thick. It has been seen by the writer varying from fifteen to twenty-two inches in thickness, and it is reported on good authority at one place, where a full measurement could not be obtained at the time of visit, to be twenty-six inches thick. It is the only ore that has been worked in the furnace at Cumberland Gap. There is such an abundance of it in the neighborhood, and it is won so cheaply, that there has been no inducement to attempt to utilize the middle ore, which is both thicker and leaner than the upper. It is hard, silicious, and not very fossiliferous. It has been seen by the writer twenty-seven inches thick, and is reported, at other places, to be thirty inches. It seems to have been originally a silicious limestone, which is now impregnated with iron. It apparently corresponds to the "hard ore" of this same period in Pennsylvania, while the upper ore seems to be the counterpart of the "soft ore" of the same State.

At Speedwell Furnace, about twenty miles below Cumberland Gap, the middle or hard ore has been used in consider-

able quantities to mix with the soft ore, a purpose for which it is well adapted. This is the way in which the two ores can be profitably utilized. The hard ore, although richer and more valuable than is now commonly supposed by iron-makers in that region, is yet too silicious to work easily in the blast furnace alone. Mixed with the soft ore, however, it can be used with very good results.

Owing to its greater thickness, there is a larger quantity of this ore in a given area than of the upper ore, although its specific gravity is not so great.

The lower ore, which occurs about two hundred feet below the middle, is but little known, and never, to the knowledge of the writer, has been mined in this region. In quality, it very much resembles the soft upper ore; so much so, that specimens of it can scarcely be distinguished from the upper ore. It is, however, thin, not having been seen by the writer more than six or seven inches in thickness. Where this ore occurs in the mountain proper, and dips away from the surface, it will be of little value, as it is too thin to be profitably mined at present under such circumstances; but where, as shown in the lowest section of the accompanying plate, it lies near the surface of the ridge for a considerable distance, it can be worked at very reasonable rates, and a large amount of ore be obtained; as, with a thickness of from six to seven inches, each square yard covered by the ore will yield nearly half a ton.

The lowest section of the accompanying plate shows the position of the ores in the Poor Valley Ridge, at Cumberland Gap, just below the Tazewell road. It will be seen that both the lower and the upper ores lie here in the most favorable position possible for easy and cheap mining, as they are both near the surface, and only covered by a slight thickness of overlying material. The upper ore has been mined for the furnace at the Gap, beginning down in the valley and working upwards towards the crest of the hill, throwing the earth behind as each successive bench of ore is raised. In this way

the pits or benches are easily drained. The cost of mining the ore here is only fifty cents per ton.

This fortunate position of the ores in the ridge is continued for several miles below Cumberland Gap, interrupted occasionally by changes in the topography, where longer spurs than usual put out from the mountain, between streams, but returning again to their position on the ridge as soon as these are passed.

The section just referred to shows the slope of the ridge on which the ore lies to be about six hundred feet in width. At places below, on the ridge, it will exceed this measurement by nearly one half. It will, therefore, be safe to estimate the breadth above drainage of the ore stratum running along this slope of the Poor Valley Ridge at six hundred feet, or two hundred yards. The ore varies in thickness from fifteen to twenty-four inches, and it is probably under rather than over the average for this region to place it at eighteen inches; but in the following estimate of the quantity of ore in this ridge it is essential to keep within limits of safety. The ore has, according to the determination by Mr. Talbutt of two samples, a specific gravity of 3.94 and 3.91. Assuming a specific gravity of 3.9, a thickness of eighteen inches, and a breadth of ore belt of six hundred feet, there will be present, for each mile of the ridge holding the ore in this position, 538,319 gross tons. This estimate is, however, too great, in that it assumes the ore stratum and the surface of the ridge to be continuous, unbroken by ravines, gullies, and streams. No accurate estimate of the amount lost in this way can be made without a detailed contour map; but it is believed that one fourth will be more than ample to cover it. Deducting one fourth as lost in this way, we still have 403,740 tons of ore present per mile of the ridge. This estimate is made exclusive of any ore below drainage at the foot of the mountain proper, for the reason that it is as yet uncertain to what depth the ore will be found soft and rich; and it will be a long time before there is any demand upon it in this position. It is

simply desired to show how vast an amount of excellent and easily obtainable ore there is lying almost at the surface.

Where the belt of soft ore is two hundred yards in width, there will be in the same ridge above drainage one hundred and fifty yards in width of the middle or hard ore. This, with a specific gravity of 3.1, and an average thickness of twenty-seven inches, will contain for each mile of the ridge 462,404 gross tons of ore. Deducting one fourth, the same proportion as in the former case, for ore lost by ravines, streams, &c., and there remain 349,303 gross tons per mile. The estimate of one fourth loss in this case is much larger than in the other, as the ore lies so deep that it is not reached by many ravines which have cut the upper ore.

It is impossible to give accurate estimates of the quantity of available ore above drainage, where it does not lie in this favorable position on the Poor Valley Ridge, without a most minute study along the whole outcrop of the ore, and a contour line map showing its elevations at different points, as it varies for every mile of the distance, running out on the ridge when that is high enough to hold it, and again setting back at the base of the mountain as the ridge falls away in height.

Prof. H. D. Rogers, in volume I, of the Geological Reports of Pennsylvania, in giving an estimate of the quantity of ore of this kind, eighteen inches thick, present in the region around Danville and Bloomsburg, Pennsylvania, places it at fifty thousand tons for each running mile of outcrop. This is based upon the assumption that the soft ore will not be found of more than an average depth of thirty yards, ere it changes to hard, lean ore, which cannot be profitably mined. This assumption does not, however, prove true in every case, as Prof. J. P. Lesley states that mining operations at Bedford, Pennsylvania, have yielded the ore in perfect condition, at a depth of several hundred feet below the outcrop. It is probably safe to assume that the amount of available soft ore will average two hundred thousand tons, per mile, for the whole distance, and at many localities will much exceed this, as it grows thicker further up the valley.

About eighteen miles above Cumberland Gap, above where Martin's creek cuts through the Poor Valley Ridge, an exposure was seen, which showed the ore, slightly tumbled and broken, as follows:

Hard silicious ore	10	inches.
Good ore, somewhat broken	21	"
Solid ore	21	"
Total	52	"

The position of the ore at this point was such that it is barely possible there may have been a repetition in this measurement as it lay on a hill-side in a considerably disturbed position. It is not believed that such is the case, however, for it was examined very carefully. A single block of ore was seen lying near, twenty-seven inches in thickness.

At lower Pennington's Gap, the ore was found standing nearly vertical (dip 80°) in the Poor Valley Ridge, and thirty-five inches in thickness. It is commonly spoken of in this region as three feet thick, and probably does reach that thickness at many places. The ore at this point is unusually coarse in structure, being formed of large rounded globules, and containing numbers of small quartz pebbles. It is difficult to account for the presence of these in the ore on the commonly received theory of its formation by replacement of limestone.

At many other places between the above-mentioned points the ore has been seen, but it was usually only in loose outcrop, not in position where its thickness could be measured. It was seen often enough, however, to prove that it extends with great persistency all along the valley, although it may vary in thickness.

The quantity of ore, per mile, increases by many tons for each additional inch in thickness of the ore bed, so that when the above noticed increase in thickness is considered, it will be seen that the estimate of the amount of ore is considerably under, rather than over, the probabilities.

Where the middle or hard ore is present, it is safe to estimate an amount of it above drainage, for each mile, fully

equal to, or greater than the soft ore. It should be distinctly remembered, however, that these last estimates are mere approximations, and are not based upon sufficient data to render them worthy the credit due to the first estimates, which were founded upon more detailed observation.

QUALITY OF THE ORE.

The soft ore is of excellent quality, producing about fifty per cent. of iron, and working easily in the furnace. The hard ore is more silicious and poorer in iron, and will probably require admixture with the soft ore, to enable it to be smelted successfully. The quality of three samples of ore, from the immediate vicinity of Cumberland Gap, is shown by the following analyses by Dr. Peter and Mr. Talbutt, from samples collected by the writer:

	1	2	3
Iron peroxide	73.935	77.380	47.965
Alumina	5.776	3.941	2.130
Lime carbonate	4.510	.420	1.230
Magnesia	.266	. . .	.194
Phosphoric acid	.319	.319	.575
Sulphuric acid	. .	. . .	trace.
Silica and insoluble silicates	11.730	15.960	43.690
Combined water	3.850	2.500	4.000
Total	100.386	100.520	99.784
Metallic iron	51.754	54.166	33.575
Phosphorus	.140	.140	.251
Specific gravity	3.914	3.942	3.190

No. 1 is the upper or soft ore from the valley near the Virginia road, a short distance above Cumberland Gap.

No. 2 is the same ore from the ridge below Cumberland Gap.

No. 3 is the middle or hard ore from the ridge near the same place as last noted.

The above analyses show in all the samples a workable per centage of iron. The amount of phosphorus present is

decidedly less than is usually characteristic of the ore at other places. As a rule in other States, this ore is decidedly phosphatic, and produces a cold-short iron; but it proves to be exceptionally pure in this vicinity.

For comparison, there is herewith appended the following analysis of the hard ore of the same geological period from Dysart's mine, Huntingdon county, Pennsylvania, by Prof. Percifer Frazer, of the University of Pennsylvania:

Sesquioxide of iron	38.48
Protoxide of iron	4.37
Silica	37.99
Alumina	9.56
Lime	1.06
Magnesia	a trace.
Alkalies	2.54
Phosphoric acid	1.48
Sulphur	.05
Loss by ignition	4.50
Total	100.04
Metallic iron	30.34

It will be seen that it is very similar in constitution to No. 3 of the analyses just before given, except that it contains a larger proportion of alumina and phosphorus.

There is also herewith given an analysis, by Dr. Peter and Mr. Talbutt, of the pig iron made at the Cumberland Gap Furnace from the soft ore of the upper bed. It is a cold-blast charcoal iron, of excellent quality and great strength. It is used for car-wheel purposes.

ANALYSIS OF COLD-BLAST, CHARCOAL PIG IRON, CUMBERLAND GAP FURNACE.

Iron	92.828
Graphitic carbon	3.260
Combined carbon	.840
Silicon	1.668
Slag	.480
Manganese	.153
Aluminum	.766
Calcium	.112
Magnesium	.270
Phosphorus	.145
Sulphur	.068
Total	100.590

This iron is hauled to the Powell river and boated down to market at Chattanooga at times of high water. It is manufactured very cheaply at the furnace; but the expense, risk, and uncertainty of the transportation to market, greatly reduce the profits on its manufacture, and leave only a narrow margin at present prices for iron.

The cheapness with which iron can be manufactured at this place will be realized when it is understood that the ore is delivered at the furnace throat for one dollar per ton, thus costing only two dollars to the ton of iron for the ore.

Furnaces lower down in Tennessee and in Alabama, smelting ore of this kind with coal or coke, produce iron at as low or lower prices than in any other part of this country. It is stated, on very competent evidence, that the Roan Iron Furnaces of Rockwood, Tennessee, make iron for less than fifteen dollars per ton.

With a railroad from the central part of the State through the mountain at Cumberland Gap, so that the Kentucky coal can be used with this ore, this locality can produce iron as cheaply as any other point in this highly favored valley, and can place it in market at lower rates.

It is destined to be one of the great iron-manufacturing regions of the country, and only awaits facilities for the transportation of its product to inaugurate a wonderful development of its resources in this direction.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

REPORT

ON THE

GEOLOGY OF A SECTION

FROM

NEAR CAMPTON, WOLFE COUNTY, TO THE MOUTH OF TROUBLESOME CREEK, BREATHITT COUNTY.

BY P. N. MOORE.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

REPORT ON THE GEOLOGY OF A SECTION FROM NEAR CAMPTON, WOLFE COUNTY, TO THE MOUTH OF TROUBLESOME CREEK, BREATHITT COUNTY.

The examination upon which this report is based was made late in the fall of 1875, for the purpose of determining something of the number and character of the coals which would be reached by a projected line of railroad, from the central part of the State, to the coal fields of the Kentucky river in Breathitt county. Owing to the lateness of the season, and the lack of time, as well as to the fact that there is no map of this region by which observations can be located with any exactness, the examination was only little more than a detailed reconnoissance. It is, therefore, highly probable, when the region comes to be examined in detail, that corrections will have to be made in the following report and the accompanying section, though it is believed that, in their general features, they are essentially correct.

As there are several different routes for the projected railroad under advisement—all, however, crossing the divide between the Red and Kentucky rivers, and subsequently the Kentucky river itself—a section of the rocks was made along this divide, from the head of Chimney Top Branch of Red river to Frozen creek; thence across the Kentucky river, and up on the south side to the mouth of Troublesome creek, which enters from the opposite side.

With the comparative merits of the different lines from an engineering stand-point this report does not deal. They will all encounter more or less difficulty in surmounting the dividing ridges between the streams. They all will reach substantially the same coal-beds, but they differ somewhat as to the

distances at which they will first strike the outcrops of the coals.

Each of the lines encounters the coals below the Conglomerate sandstone, long before those above the Conglomerate are reached. There are several of the Sub-conglomerate coals, usually of excellent quality, but, with the exception of one, not often of workable thickness. This coal is fully described by Mr. A. R. Crandall, in his report on the geology of Menifee county.

It is in quality good, but it varies from twenty-two to forty inches in thickness, with an average of perhaps thirty. The area underlaid by it is very large, and it is capable of producing a large amount of coal; but from its thinness and irregularity, it cannot be mined so cheaply as the thicker coals above the Conglomerate. These Sub-conglomerate coals of the Red river, Slate, and Beaver Creek valleys, having been examined and described in the report of Mr. Crandall, no further mention of them will be made here.

The examination for this report began at the top of the Conglomerate, at the head of Chimney Top creek, and extended in a southeasterly direction to the mouth of Troublesome creek.

TOPOGRAPHY.

The country between the Red and Kentucky rivers has its topography determined for the greater portion of its area—all of it, at least, except that near the head of Red river—by the Conglomerate sandstone.

In its western extension, from the Middle Fork of Red river westward, the dividing ridge is narrow, high, and precipitous, as the sandstone, in its resistance to erosion, forms bold and massive cliffs, often extremely picturesque in outline. The ridge grows higher and narrower to the west as the determining rock, the Conglomerate, rises in conformity with the general rise in the rock formations of the country; while to the east, toward the head of Red river, as the Conglomerate descends, and is covered by an increasing thickness of over-

lying shales and shaly sandstones, the surface of the country becomes more even, the hills lower, and with more gentle slopes, while only that portion of the country bordering closely on the main streams shows the cliff topography.

From the head of Middle Fork of Red river eastward, for several miles, the dividing ridge is narrow, and the thickness of rock above the Conglomerate slight. After passing Chimney Top and Lower Devil creeks, the surface of the country becomes more even, the hills low, not usually extending more than one hundred and fifty or two hundred feet above the branches of the main creek, while the slopes of the hills are so gentle that they can be, and in many cases now are, cultivated clear to the tops. It is one of the best agricultural regions in Eastern Kentucky. In the ridge there are numerous low gaps, leading from one stream to another, offering a comparatively easy passage for a railroad line.

The topography is of this character on both sides of the dividing ridge, at and near the heads of Upper Devil, Swift's Camp, Stillwater, and Holly creeks; but along the Red and Kentucky rivers, as well as on the lower part of the creeks just mentioned, the country is still rocky and broken by the Conglomerate cliffs.

As we proceed southeastward from Holly creek, another change takes place in the topography, which is here determined by the alternated coarse and shaly sandstones which occur above the Conglomerate.

After the Conglomerate passes beneath the drainage, there is no one member of the rock series which alone determines the topography. On the contrary, we have the hills, showing the resultant of the different resistance to erosion of massive sandstones and shales or shaly sandstones. The hills rise from four hundred and fifty to six hundred feet above the river, and present a much steeper slope, extending in about the same degree from top to bottom; but when it comes to be examined in detail, it is seen to be made up of a series of terraces, steep, and often precipitous, where the heavy, coarse standstones occur, and more gently sloping over the

shales and shaly sandstones. The coarse sandstones, from the way they resist erosive agencies, are more often exposed than the shaly beds, and they are seen in proportion to their thickness. The shales and shaly sandstones are usually covered by the talus from the overlying coarse sandstones, and good exposures are more rare.

This character of topography begins above the mouth of Holly creek, and extends as far as the field covered by this report. Above Jackson, in the dividing ridge between the river, or the short branches emptying immediately into the river and Cane creek, a heavy sandstone, about fifty feet in thickness, caps the hills, which there rise to a greater height above the river than at any place before noted.

GEOLOGY.

In the description of the topography, or the surface configuration of the country under discussion, the character of the geology has been roughly outlined, for it is the rock structure which determines the contour of the surface of any region, and no intelligible description of the topography can well be made without reference to the determining rocks.

There are in this region only the rocks of the Carboniferous formation. West and northwest, beyond the head of Middle Fork of Red river, are found rocks lower down in the geological series; but, for a description of their position, order, thickness, etc., the reader is referred to the report of Mr. A. R. Crandall, before referred to.

As may be inferred from what has already been said, the Conglomerate sandstone is by far the most prominent member of the rock series of this region, and has exerted a greater influence upon the formation of the topography than any other. It forms the rocky wall which fences in Eastern Kentucky from ready communication with other portions of the State, and, with its frowning cliffs, guards its stores of mineral wealth. It has been the most serious obstacle to the development, both material and social, of Eastern Kentucky,

for it has prevented that necessity of modern civilization, quick and cheap transportation.

From whatever point a railroad is projected to enter Eastern Kentucky, it must encounter the serious difficulty of surmounting the Conglomerate sandstone, if it would penetrate to the heart of the coal fields, where the best and thickest coals are found in such abundance that they can furnish an ample supply for generations to come—a supply upon which can be based permanent mining enterprises.

The Conglomerate is often found in two members, with a series of shales containing coal, between. The lower member is uncertain and irregular, both in occurrence and thickness; but the upper member is present all through this region, although varying somewhat in thickness. It is the most important, and is the one referred to as the Conglomerate. In thickness it is here from one hundred and fifty to two hundred feet. In character it is a coarse, massive sandstone, at places full of pebbles, and usually showing prominent cross-stratification lines. The pebbles are most abundant in the lower part of the sandstone, decreasing towards the top; and as we go to the southeast, where the greater portion of it has passed below the drainage line, and the top only is exposed, they disappear almost altogether; so that it becomes difficult to distinguish the Conglomerate from some other coarse sandstones which occur above it.

The thickness of rock above the Conglomerate at the western end of this section is small, ranging from fifty to one hundred feet, and this only in detached knobs at the heads of the small streams, while out on the points the top of the Conglomerate is often bare. This thickness increases rapidly towards the southeast, until, between Swift's Camp and Upper Devil creeks, in the neighborhood of Campton, it ranges from one hundred and twenty-five to one hundred and seventy-five feet.

In the dividing ridge at the heads of Holly and Stillwater creeks this thickness increases to two hundred feet and more; but along the lower portion of these streams it is usually less.

Above Holly creek the hills rise rapidly to twice their former elevation above the Conglomerate, in consequence of a change in the character of the prevalent rock from shaly to coarse sandstone. At the western end of the section, from the head of the Middle Fork of Red river to Swift's Camp creek, the rocks above the Conglomerate are almost entirely shales or shaly sandstones, wherever seen.

In passing above Swift's Camp creek thicker and coarser sandstones begin to be seen, which increase in frequency until they form the greater portion of the rocks.

The Conglomerate passes beneath the drainage near the mouth of Frozen creek. From this point to the mouth of Troublesome creek, coarse, massive sandstones, ranging from ten to fifty feet in thickness, are the most prominent features in the section. These sandstones are frequently exposed in cliffs on the hillsides; but, with few exceptions, they do not hold their character and position over large areas, as they frequently give place to shaly sandstones and others, which before had been shaly, become coarse and massive.

Of bituminous and clay shales, there is not in this region any great thickness. Occasional outcrops are found, but, in comparison with the great mass of shaly and coarse sandstones, they are rare; nor do they hold any great extent in area; on the contrary, they seem to be quite local, and when the attempt is made to trace them for any distance, they are usually found becoming more and more sandy, until they change insensibly to shaly sandstone.

After passing the Sub-carboniferous limestone, which lies below the Conglomerate, there is no pure limestone of any thickness found in this region. Numerous bands of dark, very silicious limestone or calcareous sandstone are found, but they are usually thin; not in any case more than four feet in thickness. In many places they do not form regular strata, but occur in large lenticular or kidney-shaped masses, lying in sandstone or shale. These kidneys are usually more silicious than the beds or strata of impure limestone. In places, some of these bands of limestone become fossiliferous, but

these cases are exceptional. So far as seen, they do not occur at regular, well-marked intervals, nor do they have any great horizonal range.

The limestones, so pure in quality and so persistent in position, which often serve as guides in the identification of coal seams near the Ohio river, seem to be entirely wanting here, and we have in their places these numerous, erratic, and untrustworthy bands of impure limestone, which are of almost no value whatever for use in geological identification.

The absence of these limestones, and the frequency with which the sandstones and shales change character, render the construction of an accurate section, and the identification of coal seams across any great interval, a matter of considerable difficulty. The absence of limestone and fine shales, as well as the character of the prevailing rock, which is a coarse mechanical sediment for the most part, indicates the prevalence throughout this region, during its deposition, of shallow waters much disturbed by currents, accompanied by frequent changes of level. There was no subsidence deep enough or long enough continued to allow the formation of pure limestones, nor were the waters quiet and land-locked lagoons, in which the fine mud could settle undisturbed, to be afterwards compacted into shale beds.

It is worthy of notice, that the Sub-carboniferous limestone, which in Ohio is thin and frequently wanting altogether, thickens from the Ohio river to the southwestward, while the limestones of the coal measures, several of which are found in Ohio, disappear soon after crossing into Kentucky.

SECTION.

Accompanying this report will be found a horizontal section showing the principal features of the geology, from the dividing ridge west of Campton to the Kentucky river, at the mouth of Troublesome creek. This section is by no means complete, and it is not offered as such. On the contrary, as already stated, it will probably be found to need considerable correction when the country comes to be examined in detail; and it

is not at all impossible that, especially in the southeastern end of the section, some of the connections between the coals may be found to be incorrect. It is believed, however, that the greater portion of the section is correct. The measurements for elevation were made with an aneroid barometer, without any correction from a check barometer, at a time of the year when atmospheric variations are often sudden and great, so that there is a liability to error from this cause. On the other hand, the measurements for level were usually made with the Kentucky river as a base, the level of this being known from actual survey, and the variations were checked as often as possible by returning to the river. The measurements for distance will probably need some correction, as they were not obtained from the most reliable sources, the existing maps of this region being very imperfect. The section is given as the best that could be accomplished with the time and means at command, and it serves very well to show the principal features of the geology of this region.

It will be seen that there is a total thickness of seven hundred and fifty feet of strata above the top of the Conglomerate included in the accompanying section. This, with the three hundred and twenty-five feet of Conglomerate and Sub-conglomerate beds, makes a total thickness of one thousand and seventy-five feet of Carboniferous rocks above the Sub-carboniferous limestone, from the river at the mouth of Troublesome creek to the edge of the coal measures.

COAL.

The coals of this region are numerous and of excellent quality, and, taken as a whole, will bear comparison with those found in any other portion of the State in quality or thickness. They are all classed as bituminous coals; but they show all the varieties of this class, known as dry-burning, caking, and cannel coals. The principal coals are of the dry or free-burning variety, while the caking or fat coals are comparatively rare. Cannel coals are abundant and of excellent quality; certain of them having a reputation second to none in the State.

As yet, this region is almost entirely undeveloped, so that it is difficult or impossible, without the most detailed and careful study, to obtain a complete section, showing the thickness and position of all of the coal seams—a study which has, as yet, not been given to it. There are numerous mines along the Kentucky river, where coal has been mined for shipment in boats down the river; but none of them are extensive, and the majority are now abandoned and have fallen in.

The practice is to open a drift from which a few boat-loads of coal are taken, when, as soon as it is far enough underground to render it a matter of some labor to get the coal to the mouth of the drift, it is abandoned, and another one opened. The so-called mines are, therefore, but a series of shallow pits.

Of late years, owing to the low price of coal in the lower markets, coal mining has not been as profitable as formerly, and but little is now mined in this region, except of the finer grades of cannel coal, which bring a higher price, and can, therefore, yet be mined and transported at a profit.

The cause of this stagnation in the mining industry is the excessive cost of transportation; due entirely to the uncertainty and danger of the river navigation. Coal-boats drawing five feet of water can only be run during high water, which can be expected but for a very small part of the year. This, therefore, necessitates the storage of large quantities of coal, often for months after it is mined, while waiting for a rise in the river sufficient to carry it off. This storage is of great detriment to the coal, as it is injured by exposure to the weather. In addition to the injury and loss by exposure, an extra cost is involved through the loss of capital lying idle for so long a time.

The boats used to carry the coal down the river can never be returned, and they are, therefore, usually sold at a great loss. The river is so difficult of navigation, that from three to five men are required to manage each boat, or one man to about each thousand bushels of coal; the boats usually holding from three to five thousand bushels of coal each.

In addition to these necessary and inevitable expenses, there is great risk involved in the navigation of the river, a large proportion of the boats never reaching their destination.

These combined causes make the cost of coal, at the markets along the lower river, so great, that Pennsylvania coal is brought down the Ohio river, up the Kentucky, and sold at a less price in Frankfort than the coal from this region. Thus, the work which has been done by the State in improving the navigation of the Kentucky river, for a part of its course only, actually operates against the interests of Kentucky coal miners, instead of furthering them, for it enables Pennsylvania coal to compete with them in their own markets, without assisting them in any degree. Were Kentucky river slack-watered to the mines, so that coal could be shipped at nearly all seasons of the year, and the empty barges returned cheaply, this region could supply coal to the whole of that part of the State bordering the river, at prices which would drive all foreign coal from the market; and it could even do a large business on the Ohio river in the fine cannel coals in which it abounds.

Until improved means of transportation are furnished this region, either by slack-water or railroad, there can be no extensive and regularly conducted mining enterprises. The fine-grade cannel coals will probably continue to be mined in a precarious and haphazard way, as they commonly bring a price sufficient to pay a small profit over the risk and expense of transportation; but, with this exception, the great body of coal will remain untouched.

The lowest coal mines on the Kentucky river are near the mouth of the South Fork, at Beattyville and Proctor, where one of the Sub-conglomerate coals of excellent quality is mined. There are few mines above this for about twenty-five to thirty miles along the river, until near the mouth of Holly creek. Between these places the river runs through "the narrows," a gorge or cañon which it has cut through the Conglomerate. For most of this distance the Sub-conglomerate coals are beneath the level of the river, while the hills

do not rise sufficiently high over the Conglomerate, until some distance back from the river, to hold the coals which have been mined further up.

Above Holly creek, banks have been opened every few miles, until the last are reached about five miles above Hazard, in Perry county. Most of these, as already stated, are abandoned, and have fallen in, so that exposures of the coal that can be measured are rare. Back from the river, openings or exposures of the coals are very few, as there has been no inducement to mine coal while wood is still the most common household fuel in use. In studying the geology of this country, therefore, reliance has to be placed mainly on natural exposures or outcrops of coal; so that it is a matter of considerable difficulty to obtain a complete section, showing the position of all the coals.

In the accompanying section the position of the coals shown is well ascertained; but, from the reasons just given, the thickness has not been accurately determined in every case.

The change in the general character of the rocks from that of the region nearer the Ohio river, which has been referred to before, is accompanied, to a certain extent, with a change in the coals; but the region has not yet been examined over a sufficiently large area to enable a generalization as to the number and equivalency of the coal seams. The section bears in its lower part a resemblance to that of the country near the Ohio river; but, after the first two hundred and fifty feet above the Conglomerate is passed, the resemblance is not so great. There seem to be, here, greater changes between coals, within short distances, than are common farther north.

In the section accompanying this report are shown eight coal seams above the Conglomerate. From the detailed vertical sections given in the horizontal section, the evidence upon which this identification is based can be seen. The dotted lines connecting the coals in the section indicate the probable connection between them; but it must be distinctly

understood that this is not positively asserted. It is only the connection which seems the most probable, with our present knowledge.

The first coal of the section, the equivalent of coal No. 1 of the Greenup County section, and of Ohio Geological Reports, occurs from twenty to fifty feet above the top of the Conglomerate. It is first opened near Campton, on Swift's Camp creek, and also on Bear Pen Branch of Upper Devil creek. Its position, here, is about twenty-five feet above the top of the Conglomerate. Its thickness is from twenty-four to thirty inches. It is a fat or caking coal, of very good quality, especially the lower portion of it. In this respect it differs from the No. 1 coal further north, which is there a typical dry-burning or furnace coal. It is the famous Jackson and Briar Hill coal, with which over half of the iron made in Ohio is smelted. The per centage of sulphur present varies considerably, but is usually low. It is seen at a number of places along the river, holding an average thickness of thirty inches. Below the mouth of Frozen creek, near Mr. Nathan Day's, is an old mine, now fallen in, where the coal is said to be thirty-six inches thick in some of the rooms. Below the mouth of Holly creek, on the Holland place, is an exposure where it measured thirty-four inches; but this includes a shale parting of several inches in thickness. On Frozen creek it is seen at a number of places near the mouth, usually about twenty-eight inches thick; but above this stream it has not been seen by the writer. A coal, which is probably this one, is reported on the old Cockrill farm. It probably goes under the river not far above. This coal is an excellent blacksmith fuel, and would doubtless make a firm, hard coke. Coal of this quality is rare in this part of the State, as the majority of the coals are of the soft, free-burning, non-coking character; and although this is thin, it will doubtless eventually become valuable.

The following analyses by Dr. Peter and Mr. Talbutt, show something of the character of this coal in this region:

	1	2
Moisture	3.74	2.50
Volatile combustible matter	35.52	41.10
Fixed carbon	52.64	49.22
Ash	8.10	7.18
Total	100.00	100.00
Coke	60.74	56.40
Sulphur	2.466	0.818
Specific gravity	1.336	1.300

No. 1 is an average sample by Mr. A. R. Crandall, from C. M. Hanks' bank, at Campton, Wolfe county.

No. 2 is an average sample, by the writer, of coal from an opening above Wm. Day's, on Frozen creek, Breathitt county.

COAL NO. 2.

About seventy-five feet above the coal just described, has been found at a few places, another coal seam, which is probably the equivalent of coal No. 2 of the Greenup section. Like that, it is usually thin, not having been seen more than twenty inches thick. At other places it is less, not more than twelve inches. It is not mined at any place, and, consequently, no samples were procured for analysis. It is best shown on the branches of Swift's Camp creek, above Campton.

COAL NO. 3.

At a distance ranging from one hundred and forty to one hundred and ninety feet above the Conglomerate is found a coal, which, from its character and position, seems to be the equivalent of coal No. 3 of the Greenup section.

It is better known than any other coal of this region, for the reason that it has been most extensively worked. The mines on the Kentucky river, from Holly to Quicksand creek, are all in this coal, with the single exception of the entry in the No. 1 coal already noted. On this account, also, better opportunities for sampling the coal are given.

From our present knowledge, this coal seems to be one of the most regular and trustworthy of any in this region, which characteristics it holds all through Eastern Kentucky, as far as we now know it. Along the ridge, between the Red and Kentucky rivers, it is first opened at the head of one branch of Upper Devil creek, about four and a half miles from Campton, at the Hobbs bank.

The coal here consists of three members or divisions, separated by thin shale partings. The following is the section of the coal at this place:

Coal	2′	
Shale parting		3″
Coal	1′	8″
Shale parting		8″
Coal	1′	3″

Giving us a total thickness of four feet eleven inches of coal. The quality of the coal here is excellent, as will be shown further along. It is somewhat sulphurous in appearance; but the pyrites is in small flakes, which hardly form an appreciable per centage of the whole. This splendid coal is the first of a thickness greater than three feet, which would be reached by a railroad, after crossing Red river.

On the Kentucky river, the first opening of this coal is at the Holland mine, below the mouth of Holly creek. The coal is here about three feet in thickness, or a little less. Along the river, the thickness varies from three to three and one half feet of coal. The thickness, including parting, is usually much more, as there is commonly a slate parting, which varies from three to twelve inches. This is usually measured with the coal; hence it is commonly called four feet thick.

At the Hobbs bank, this coal is about four hundred feet above the river. It rapidly descends to the southeast, until, at the Holland bank, it is only a little over three hundred feet above. At Jackson it is only one hundred feet, while above this it descends still more rapidly, until, at the mouth of Quicksand creek, it is at the level of low water in the river. From this point to the end of the section the dip changes, and the rocks are horizontal, or nearly so. From some observations

made above the mouth of Troublesome creek, it seems probable that the coal,there,dips in the opposite direction, and that it rises more rapidly than the rise in the level of the river. This conclusion is based upon an identification of a coal on Wolf creek, which is not as yet supported by sufficient stratigraphical evidence to be by any means certain, as the examinations in that region have not yet been detailed. The coal on Wolf creek resembles the No. 3 very closely in physical character and chemical constitution, as will be seen by the analyses appended. It is thicker here than it is known to be at any other locality below. It is reported, on good authority, to be seven feet in thickness. When visited by the writer, the drift had caved in, so that the whole thickness could not be seen; but satisfactory evidence was obtained, by measuring some of the timbers which had been cut to support the roof of the drift, that the coal is more than six feet thick.

Below Jackson, at Spencer's mine, this coal, with a total thickness of about four feet, including partings, shows a little less than three and one half feet of coal. At Cardwell's bank, near Jackson, it is nearly the same. Along the river, opposite and above Jackson, this coal has been mined at many places, none of which are now open, so that it can be examined. It is stated that the shale parting grows gradually thicker and the coal thinner further up stream. This statement is corroborated by the following section, at a natural exposure of the coal in the bank of the river at the mouth of Stray branch:

Coal	1′	9″
Shale parting	1′	8″
Coal		5″
Shale parting		4″
Coal		2″
Shale parting		2″
Coal		1″
Shale parting	1′	2″
Coal		7″

The total thickness of coal in the above section is thirty-six inches; but the numerous thin bands into which it is divided, and the shale partings between, show that at this point, during the formation of the coal, it was subject to frequent fluctua-

tions of level, probably not of any great extent, but sufficient to check the growth of the coal vegetation, and to allow the deposition of layers of mud, which became afterwards hardened into the clay shale partings.

These frequent old openings in this coal, along the river, identify it beyond doubt, and also show the rate of dip.

In character, it is usually a distinctly laminated and dry-burning coal, with considerable fibrous coal or mineral charcoal between the laminæ. At places portions of it are bituminous enough to coke, but this is not its general character.

The amount of sulphur present varies considerably, but is usually low, as is also the ash, while the per centage of fixed carbon is high. These three qualifications render the coal an excellent fuel for general purposes, and when considered in connection with its dry-burning, non-caking character, render it extremely probable that the coal would make a successful furnace fuel for the manufacture of iron.

The following analyses, by Dr. Peter and Mr. Talbutt, show the composition of this coal at several places:

	1	2	3	4
Moisture	3.50	3.56	4.90	2.76
Volatile combustible matters	35.20	33.56	35.30	36.60
Fixed carbon	56.70	58.38	55.50	56.50
Ash	4.60	4.50	4.30	4.06
Total	100.00	100.00	100.00	100.00
Coke	61.30	62.88	59.80	60.56
Sulphur	1.189	1.381	3.153	0.865
Specific gravity	1.294	1.297	1.290	1.290

No. 1 is from the Hobbs' bank, at the head of Upper Devil creek. Average sample by the writer.

No. 2 is from Wm. Spencer's mine on Kentucky river, below Jackson. Average sample by the writer.

No. 3 is from the Holland mine, below the mouth of Holly creek. Sample taken by the writer from a large pile of coal which had lain exposed to the weather for about one year.

No. 4 is from the South mine, on Wolf creek. Average sample by Mr. J. R. Procter and the writer, from a large pile which had also been exposed to the weather for about a year. As already stated, this coal is not positively identified as the same as the others, but for convenience it is given with them. It will be noted that its chemical composition closely resembles the others.

Above coal No. 3 the remaining coals of the section are not so well known, either as to position or character, for the reason that they have not been so extensively mined, and outcrops are comparatively rare. With our present knowledge, the coals above No. 3 seem to be more irregular and uncertain than that one; although it is possible, when they are better known, and a more complete series of sections obtained, that they will be found to be more uniform than is now supposed. For this reason, the attempt will not be made to number and classify them at present. They will be described in their approximate order.

The first workable cannel coals near the line of this section are found above coal No. 3. Such coals occur, at various levels, all through this region; but the lower ones are usually thin.

On the Kentucky river, at a distance varying from thirty to fifty feet above coal No. 3, is found another coal, usually about two feet thick. It is a rather fat, bituminous coal, of very good quality; but it has not been worked. It is seen of this thickness at the Spencer and Cardwell banks, below Jackson. Still further down the river, it is reported to be more than three feet thick, but it was not seen by the writer. Above Jackson this coal is thinner.

At many localities the proper level for this coal is occupied by a shale or sandstone, while at about seventy to eighty feet above Coal No. 3 we find a cannel coal. This is the cannel coal which is seen in the river hill about one mile below Wm. Spencer's. It is not well exposed here, but it seems to be thin. It is probably also the cannel coal seen at G. W. Johnson's, near the head of Nichols Fork of Frozen creek. It is

here seen in outcrop along the hillsides at many places, but has not yet been opened so as to show its full thickness. Blocks of coal nearly two feet in thickness were seen tumbled out on the hillside; but beyond this there was nothing to determine its thickness.

The frequency of outcrop of this coal in this neighborhood shows it to be quite a persistent seam, and it is to be hoped that, when it is opened, it will be found of workable thickness. Two varieties of cannel coal are seen here, both probably from the same bed or seam. One is hard, of very uniform, rather coarse-grained structure, showing perfect conchoidal fracture, and abounding in brilliantly polished surfaces or slickensides, which have probably been caused by faults or slips in the hill squeezing and pressing the coal upon itself. This coal contains a considerable proportion of earthy matter, as will be seen by the analysis further along; and to this cause may possibly be due the readiness with which it assumes a polish.

Fortunately, this variety of the coal seems to be much less abundant than that other, which shows a partly laminated structure, irregular fracture, is of a less homogeneous nature, and not nearly so handsome; but which proves, on analysis, to be one of the best cannel coals of this whole region. It is sometimes called the "curly cannel," owing to its peculiar structure.

The cannel coal which is found at John Murphy's, on Stillwater creek, is probably the equivalent of this seam.

The cannel coal which is mined on Quicksand creek, about one mile above its mouth, is probably also the same. This coal shows a total thickness of twenty-five to twenty-six inches, of which the upper eight inches is bituminous, leaving only a thickness of seventeen to eighteen inches of pure cannel. It has an excellent reputation in the lower markets, and commands a high price; so that, in spite of its being so thin, it is mined at a profit. The analysis of this coal is given further along in this report.

On George's branch, which empties into the Kentucky river several miles above the mouth of Troublesome creek, a cannel coal of excellent quality is mined, which, if the supposition as to the equivalency of the Wolf Creek coal with the No. 3 be correct, is the same coal as that just described on Quicksand creek. This coal shows a total thickness of thirty-four to thirty-six inches, of which twenty-two to twenty-four inches is cannel coal, the remainder bituminous. Like the Quicksand Creek coal, this has an excellent reputation in market, and brings the highest price. It is much sought after by consumers, for household fuel.

The position of this coal at the various localities corresponds very well with that of coal No. 4 of the Greenup County section.

At a distance ranging from sixty to eighty feet above the last described coal another has been seen in imperfect outcrop at a number of places, but it is not mined at any place; so that very little is known of its thickness or quality. The stain, or the weathered outcrop of it, is frequently seen. On a short branch emptying into the Kentucky river from the opposite side, above the mouth of Quicksand creek, this coal is washed bare by the stream, and shows a thickness of thirty inches. It is a bright, glistening, caking coal, of very good quality, as far as could be judged from the limited exposure.

At the Haddock mines, on the bank of the river above Troublesome creek, this coal has been found as a cannel coal, and is reported to be twenty inches thick. The outcrop was not sufficient, when seen by the writer, to prove anything as to its thickness; but it showed the existence of cannel coal at that point.

From one hundred and ten to one hundred and twenty-five feet above this last coal, at a height, where best known, of two hundred and fifty feet above the Kentucky river, is found the most valuable cannel coal of this region. It is commonly known as the Haddock coal, as it is mined most largely at the Haddock mines, at the mouth of Troublesome creek. This is the thickest cannel coal on the line of this section, and in

quality it is equal to any. It does not contain as much volatile combustible matter as some of the other cannel coals, and will not make quite so brilliant a fire, but it contains less ash than the most of the others. It is mined, for this region, in considerable quantities at the Haddock and Sewell mines, near the mouth of Troublesome creek. Here it usually shows a thickness of thirty-four inches of cannel coal, with ten to twelve inches of bituminous coal above. In one of the drifts of the Sewell mines there was seen thirty-six inches of cannel coal, with ten inches of bituminous above; and the miners report that, in some rooms, the cannel coal reaches a thickness of forty-eight inches. The miners "bear in" on the soft bituminous coal above, and then wedge up the cannel coal in large blocks.

This coal is also found on the same side of the river two or three miles below, on land belonging to Wm. Spencer. It has never been mined here, but it shows at an outcrop, imperfectly seen, thirty-four inches thick, and it is reported to be three inches thicker when the whole thickness is exposed. Of this, all but the upper four or five inches is cannel coal. Below this point this coal has not been mined or even opened so as to show its thickness, at any point known to the writer; but it has been found as a stain at some places. It is said to be opened on the east bank of the river a short distance below the mouth of Troublesome creek, but the place has not yet been visited by any member of the Survey. Whether the coal extends down the river, holding its thickness for any distance, is unknown; but from the well-known uncertain character of cannel coal, it is at least doubtful. However, it has been found at enough places, widely separated from each other, to prove that it underlies a large area, sufficiently large to be able to supply all the demands of an extensive mining industry for a long time to come.

In the hill at the Haddock mines, at a distance of one hundred and ten feet above the main cannel coal, a coal has been found, which is reported to be a semi-cannel coal, four feet in thickness; but it had caved in at the time of examination by

the writer, so that nothing could be seen of it. The "stain" or "sign" of this coal was found at other places, enough to show that it holds its position with considerable persistence.

Fifty feet above this coal is found another, which has been mined on the opposite side of the river from the Haddock mines, by Mr. J. Wells. It here shows the following section:

Coal		11 inches.
Shale parting		2 "
Coal	1 foot	1 "
Shale parting		4 "
Coal	1 "	3 "

A total thickness of three feet three inches coal, excluding shale parting. It is a dry-burning, bituminous coal, quite free from sulphur, but carrying a rather large per centage of ash, as shown by the following analysis, by Dr. Peter and Mr. Talbutt, of an average sample taken by the writer. The coal sampled from was near the outcrop, and hence the analysis may possibly show more ash than properly belongs to it:

Moisture	2.78
Volatile combustible matter	35.52
Fixed carbon	44.94
Ash	16.76
Total	100.00
Coke	61.70
Sulphur	1.423
Specific gravity	1.398

This is the highest coal geologically in this region of which anything is definitely known. At several localities a coal stain is found immediately below the massive, heavy sandstone which caps the hills back from the river, but nothing is known as to its character or thickness.

UNDETERMINED COALS.

As the examination made of this region was so largely of the nature of a reconnoissance, many exposures of coal were seen—especially when at some distance to one side of the line of the section—the geological equivalency of which was not determined, owing to lack of time for detailed examination.

The coals on Wolf creek and George's branch should really be classed here, as they are by no means certainly identified.

On main Frozen creek, above the house of Mr. Green Tolby, a coal is found about one hundred and seventy-five feet above the bed of the creek, in natural outcrop below a sandstone cliff, showing a thickness of three feet nine inches clear coal, without any perceptible parting.

On Stillwater and Gilmore creeks, in Wolfe county, cannel coal is found at a number of places, but its equivalency has not yet been determined. At Mr. James F. Ely's, a cannel coal has been opened; but the drift has now fallen in, so that it is partly covered. This is asserted to be three and one half feet in thickness. A thickness of two and one half feet was seen by the writer at an exposure which evidently did not show the whole thickness of the bed. The exposure was such that an average sample for analysis could not be obtained. A hand specimen was, however, subjected to analysis, with the result of showing an excessive per centage of ash. The per centage is so large that it seems possible the specimen selected may have been worse than the average of the coal, although not intentionally selected as such. The general appearance of the coal does not indicate so large a per centage of ash; and it is but justice that this analysis should not be allowed to go unexplained, to the injury of the coal, before an average sample can be selected and analyzed.

On Stillwater creek, at Mr. John W. Faulkner's, a cannel coal is found, which is commonly reported to be three feet thick. Only about ten inches of the upper part of the bed were seen at time of visit, the rest being covered by mud and water. From this also a hand specimen was taken for analysis, which showed a large per centage of ash, not quite so large as in the last case, however. The same caution should be held in regard to this coal as the last; but against it is the fact that it has the reputation, among those who have burned it, of carrying much ash. At John Murphy's, on Stillwater creek, a cannel coal is found outcropping with considerable regularity in the hills back of his house. It has

never been dug into or opened, and nothing is known as to its thickness. It is the coal before referred to as probably the first coal above No. 3.

On Troublesome creek, about fifteen miles from its mouth, below the mouth of Buckhorn creek, on the Roberts farm, is a coal which shows the following section:

Bituminous coal	1′ 10″
Shale parting	3″
Bituminous coal	1′ 5″
Shale parting	10″
Cannel coal	1′ 10″

A total thickness of five feet one inch coal.

There has been considerable excitement in regard to this coal, and very exaggerated reports were in circulation concerning it. The thickness of the whole bed was commonly stated as being cannel coal, when in reality not more than one third of it is of that kind. It is, however, a valuable seam of coal, as it can be mined very cheaply, owing to its thickness. The quality of the different members of this coal is shown by the following analyses, by Dr. Peter and Mr. Talbutt, from average samples taken by myself:

	1	2	3
Moisture	3.30	2.20	3.40
Volatile combustible matter	31.44	39.20	43.40
Fixed carbon	49.76	51.14	46.96
Ash	15.50	7.46	6.24
Total	100.00	100 00	100.00
Coke	65.26	58.60	53.20
Sulphur	.991	2.525	.630
Specific gravity	1.405	1.290	1.280

No. 1 is the upper seam—bituminous.

No. 2 is the middle seam—bituminous.

No. 3 is the bottom seam—cannel.

There is a salt well on the Kentucky river, opposite the mouth of Troublesome creek, which is reported to have passed through four coals in sinking to its present depth of four hundred and ten feet. Measurements of coals by boring

are always liable to error, especially if, as in this case, the boring was not made for the especial purpose of finding coal, but to obtain salt water, as the borings are very apt to become mixed by the drill. It is also difficult to tell the exact line of passage from one stratum of rock to another. The well was sunk in 1846 by Col. L. C. Bohannan. The records of the well have, unfortunately, been lost; but, from memory, Col. Bohannan states the position and thickness of the coals passed through approximately, as follows:

First, about ten feet below the surface a coal, reported two feet six inches thick.

Second, from forty to fifty feet below the surface another coal, reported three feet thick.

Third, about two hundred feet from the surface a coal, said to be about four feet thick.

Fourth, after passing through a very thick, coarse sandstone, a coal was reached at a depth of three hundred and eighty to three hundred and ninety feet from the surface, which is said to be of the unusual thickness of ten feet.

This is probably one of the Sub-conglomerate coals, which at other places is associated with a great thickness of bituminous shale, often mistaken for coal. This is peculiarly liable to be the case when nothing but the finely comminuted fragments of the material from the well can be had for examination. It is hardly probable that the Sub-conglomerate coal, from what we know of it at other places, would thicken so remarkably in this direction. The heavy sandstone reported as having been passed through before reaching the last coal, is very probably the Conglomerate.

The boring is, therefore, interesting, as showing the salt-bearing rock to be either the Conglomerate or the shales below. Nothing definite could be learned as to the amount of brine yielded by this well, or its strength. The prevalent impression in regard to its strength is, that it requires eighty gallons of brine to produce one bushel of salt.

At Mr. Marcum's, above the Haddock mines, two coals have been mined near the river, one of them about seventy-

five feet above the river, and the other about twenty. The upper coal is three feet thick, and is reported to be one of the very best coals mined on the river. The lower was not seen, as it was covered at the time of visit. There is another coal two feet thick above it, separated by about seven feet of space. The upper coal was seen.

At Mr. McIntosh's, about two miles above, a coal about forty feet above the river has been considerably mined, but has now fallen in. This coal was not seen, but was reported to be four feet four inches thick by the former owner.

In addition to the above, numerous exposures of coals too thin for working have been seen, ranging from a few inches in thickness up to two feet. The positions of some of these are known to be in the regular series of the coals, while others seem to be erratic and intercalated seams of no great horizontal range.

QUALITY OF THE CANNEL COALS.

The cannel coals of this region are, for the present, and probably will be for some time to come, more valuable than any other. They will always command a higher price per ton than other coals, on account of their excellent qualities as household fuels and for steam-making. They are also valuable for the manufacture of gas; but their use is limited in this respect, owing to the poor quality of the coke resulting after the volatile portions of the coal have been driven off. The greater thickness and regularity of some of the other coals may eventually, when facilities for transportation become adequate, render them the most valuable, as they can be more cheaply mined than the cannel coals; but the latter, when of good quality and reasonably free from ash, will always be in demand.

As has been already indicated in the descriptions of individual seams, these cannel coals vary greatly in quality as well as thickness, and the same seam often changes thickness and quality very suddenly.

The following analyses, by Dr. Peter and Mr. Talbutt, will serve to show very fairly the different qualities of these coals:

	1	2	3	4	5	6	7
Moisture	1.30	0.94	2.10	1.60	1.20	1.16	1.30
Volatile combustible matter	47.00	52.38	43.10	43.20	58.80	44.58	41.40
Fixed carbon	44.40	35.54	43.36	33.80	35.30	32.76	28.20
Ash	7.30	11.14	11.44	21.40	4.70	21.50	29.10
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Coke	51.70	46.68	54.80	55.20	40.00	54.26	57.30
Sulphur	1.574	1.423	6.119	2.549	. . .	0.530	0.846
Specific gravity	1.265	1.280	1.328	1.360	1.180	1.383	1.434

No. 1 is an average sample from the Haddock mine. Sampled from the seam in the mine.

No. 2 from George's branch. Average sample from the stock pile at mouth of pit.

No. 3 from the Quicksand Creek mines. Average sample from the stock pile of coal at the mouth of the pit, taken by Mr. J. R. Procter.

No. 4 is from Frozen creek, near G. W. Johnson's. Sample averaged from a small pile of coal, not more than one or two tons. This is the coal which shows the brilliantly polished faces.

No. 5 from near the same locality. Analysis from a single specimen only. This specimen was not originally selected for analysis, and may, therefore, possibly represent the coal at this place as better than the average.

No. 6 from John W Faulkner's, Stillwater creek. Analysis from single specimen.

No. 7 from James F. Ely's, Gilmore creek. Analysis from single specimen.

It will be noted that the last three analyses from single specimens show a very small per centage of sulphur, probably considerably less than the average of the coal would show if representative samples were selected. This is liable to be the case when single specimens are used for analysis, as it is very difficult to obtain one which is exactly representative in every respect.

With the exception of Nos. 4, 6, and 7, of which No. 4 is the only average sample, and consequently the only one which should be regarded as good evidence of the quality of the coal, the above analyses show coals of excellent quality, which will compare favorably with the best cannel coals of other localities.

For the purpose of such comparison, the following table of analyses of cannel coals is appended:

	1	2	3	4
Moisture	1.30	1.50	.....	.....
Volatile combustible matter	59.60	52.20	43.37	50.18
Fixed carbon	27.00	40.60	46.50	46.42
Ash	12.10	5.70	10.10	3.40
Total	100.00	100.00	...	100.00
Coke	39.10	46.30	...	.....
Sulphur	1.896	0.782	.....	.....
Specific gravity	1.213	1.306	1.27	.....

No. 1 is the well-known Breckinridge cannel coal, Breckinridge county, Kentucky. Analysis by Dr. Peter and Mr. Talbutt. Average sample by Mr. C. J. Norwood.

No. 2 the Hunnewell cannel coal, Greenup county, Kentucky. Analysis by Dr. Peter and Mr. Talbutt.

No. 3 Kanawha cannel coal, below falls of Kanawha Falls, West Virginia. Analysis by U. R. Johnson; copied from his work on coals.

No. 4 the celebrated Wigan cannel coal, from Lancashire, England. Analysis by Heddle.

CONCLUSIONS.

A brief summary of the principal points of economical importance in the foregoing report may not be out of place here.

Of the eight coals above the Conglomerate shown in the accompanying section, five are of workable thickness, considering a coal of two and one half feet as workable. These five coals range in thickness from two and one half to six feet.

Of the three remaining coals: of one nothing is yet known as to its thickness or quality; one is probably too thin to pay for working; while a third has been mined, although only a little over two feet thick. It is reported considerably thicker at other places, and very probably is so; but it cannot be stated positively as such, as it has not been seen by the writer.

Three of these coals are at places cannel coal, two of them workable, both ordinarily of excellent quality. In addition to the coals above the Conglomerate, there is at least one workable coal below, which is of excellent quality and covers a large area.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

REPORT

ON THE

CHINN'S BRANCH CANNEL COAL DISTRICT.

BY A. R. CRANDALL.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

REPORT ON THE CHINN'S BRANCH CANNEL COAL DISTRICT.

The Chinn's Branch and Indian Run Cannel Coal Region is one of a number of areas in Eastern Kentucky in which is found a cannel coal of workable thickness. As these cannel beds are not continuous over large areas, like the beds of common bituminous coal, it seems desirable to consider somewhat in detail those areas in which cannel coal is prominent, to call attention to them as suitable fields for business enterprise, and to furnish a ready means of comparison of the cannel coal regions when the work shall have been completed.

The Chinn's Branch district is most likely to receive early attention, from the fact that it is the most easily accessible of any of the cannel regions, though in extent it is much less than some others, and though the coal ranks second in quality to the deposits of some of the interior counties. It is the nearest coal region to be reached by the lower Ohio river trade, being but 130 miles from Cincinnati, and at the westernmost outcrop along the river of workable beds of coal. Indeed, it seems unaccountable that so little should have been done to develop this locality. It appears, however, that as early as 1859 the Maysville Manufacturing and Mining Company was formed to develop the cannel coal of what was known as the Caroline tract, including the greater part of the cannel coal area of this region, for the purpose of manufacturing illuminating oil. But the discovery of petroleum deposits in Pennsylvania operated to break up this enterprise; and what with the breaking out of the civil war, and the want of method since, the property has not been made profitable to the company.

An examination of the region shows that it occupies, geologically, that part of the vertical section which includes nearly all of the valuable beds, both of coal and of iron ore, of this eastern field. (See General Section, Report on the Geology of Greenup, Boyd, &c., Vol. II, New Series.) Some of these

beds are too thin in this locality to be of any economic value at present. Coal No. 1, of the series above the conglomerate, is below the drainage, and though nothing is known of its value here, yet it may properly be left out of the list of workable beds, as also may Coal No. 2, which is too thin, where exposed, to interest any one except the geologist. Both beds are important in any comparison with other localities. The highest beds in this locality are the "Red Kidney" iron ore and Coal No. 7, the former near the top of the hills at the head of Chinn's Branch, in its ordinary relation to the latter, or separated from it by twenty to twenty-five feet of greenish shaly rock.

The cannel of this district is No. 4 of the series. The beds above and below are so well marked and so regular as to leave no doubt as to its place in the general section. Coal 4 is ordinarily a common bituminous bed. In this region this is replaced, wholly or in part, by cannel coal. The same is true of Coal No. 4 in the Hunnewell and the Stinson Creek regions. There are, however, other beds that exhibit local changes to cannel coal, and, considering this and the local character of the cannel coals, there would seem to be very little antecedent reason for supposing that the beds found at considerable intervals in the eastern coal field of Kentucky are also the equivalent of the Chinn's Branch and the Hunnewell deposits. The evidence at hand goes to show that in Morgan county the Pierat coal, and the upper cannel near West Liberty, and also the Breathitt county cannel, are the equivalent of the Chinn's Branch cannel seam, though the sections in the several localities differ very much as a whole; and further study of those regions may not sustain this conclusion.

The vertical section in the Chinn's Branch region differs in no very important respect from the typical section of Greenup, Boyd, and Carter counties already referred to, all the horizons of coal and of iron ore in that portion of the general section represented by the rocks of this region being well defined. The beds of economic value are of Coals 3, 4, and 7, with the possible addition of Coal 6, and of iron ores, the

limestone ore, and two kidney ores of the upper part of the section; the block ore near the horizon of Coal 4 being of little value, as is usual where that bed is prominent, either as cannel or a common bituminous coal.

Coal 3 is perhaps the most reliable bed in this region. It has an average thickness of about three feet, separated into two parts by about ten inches of clay shale or "draw-slate." It is overlaid by a few feet of shale, with thick sandstone above, and rests on the usual under-clay. This coal has not, until recently, come into favorable notice in this region, though the equivalent of this bed in Lawrence county, the Peach Orchard coal, has long been favorably known. By the enterprise of Mr. Bates, of the Eastern Kentucky Railway Company, this coal, as found in some parts of Greenup, has been shown to be a valuable bed, and on examination in the region in question, it is found that No. 3 is an exceptionally good coal, and that though it is not in great thickness, yet it is constant and easily mined. It is a splint coal, and bears transportation well, and is an exellent grate coal.

An analysis made for the Company by Dr. Peter shows the following, which may be regarded as an index of the quality of the coal:

Specific gravity	1.319
Moisture	5.00
Volatile combustible matter	39.00
Fixed carbon	49.88
Ash	6.12
Sulphur	1.986

The cannel coal of workable thickness appears to be limited in this region to an area oblong in outline, having its axis along a line from the old Fulton mines, near the landing, to a point on Indian Run, in the East Fork valley. How far beyond Indian Run, and how wide the area of cannel coal of workable thickness, has not been fully determined; but it may reasonably be estimated at from 1,500 to 2,000 acres. Several hundred acres of this area, belonging to the Fulton tract, have already been worked out, as also several narrow points in the valley of Chinn's Branch, on the Caroline tract;

but the great body of coal, covering a considerable portion of the latter tract, remains to be mined. The best information obtainable as to the thickness on the old Fulton tract gives it an average of about three feet. Further up, on Chinn's Branch, the bed has reached a thickness of four and a half feet. On Indian Run it is about two feet, but superior to the thicker part for gas-making. Like all cannel coals, it will probably be found variable in thickness and quality in the working of the bed. On the Indian Run the bed is accompanied by common bituminous coal, one foot on top and six to eight inches below, making the whole bed about the same in thickness as the average on Chinn's Branch, where the whole thickness is cannel.

In either case, the under-clay and the overlying rocks are essentially the same, and there are apparently no features on which more than a rough estimate of the quantity of cannel coal in this region could be based. A medium specific gravity would give about 1,500 tons, of 2,240 pounds to the acre, for each foot of thickness, or 4,500 tons for three feet, and 4,500,000 tons to the thousand acres. At the very smallest estimate, both as to the area and the thickness of the bed, the amount of cannel coal in this field, and lying within three to six miles of the Ohio river, is sufficient to warrant a systematic development of the territory, to say nothing of Coal 3, already described, and the coals above.

The only analyses of the cannel of this locality on record are two made for the Company by Dr. Peter, as follows:

	Chinn's Branch.	Indian Run.
Specific gravity	1.331	1.286
Moisture	4.80	2.00
Volatile combustible matter	36.90	47.36
Fixed carbon	51.20	38.24
Ash	7.10	12.40
Sulphur	3.977	1.554

Coal 6 has not been opened sufficiently to show its thickness and value. The evidence goes to show that it is present

at its proper level, 125 to 130 feet above Coal 4, probably over the whole region.

Coal 7, 45 feet higher up, has a thickness of three to three and one half feet of excellent coal, though the area is reduced to a comparatively small limit, the bed being near the top of the hill. This is the Coalton coal. In quality it is about the same as elsewhere. Entries have been driven, and a considerable amount of coal shipped from the ridge between Indian Run and Wolfpen Branch of Ash Creek. The two lower parts of the bed are uniformly present, separated by the usual thin parting. The upper part is said to be represented at some points by a few inches of coal, inferior in quality to the lower parts, as is usual with this bed elsewhere. The following measurements made at one entry agree substantially with those made at several others along the ridge:

	Feet.	Inches.
Overlying shaly rock, thickness not shown.		
Coal	2	
Slate parting		1
Coal	1	6
Under-clay, thickness not shown.		

The following analysis of an average sample from stock pile, together with that of the Coalton coal, as mined on Dry Branch by the Ashland Company, will serve to indicate the value of the bed, as to quality, in this region. (See remarks on the iron-making qualities of Coal 7, Part V, Vol. 1, New Series, Kentucky Reports.):

	Coal 7.	Coal 7.
	Head of Chinn's Branch.	Coalton, Dry Branch.
Specific gravity	1.324	1.340
Moisture	6.00	4.40
Volatile combustible matter	33.48	31.10
Fixed carbon	56.14	57.90
Ash	4.38	6.60
Sulphur	2.33	2.098

The iron ores of this locality are those of the Hanging Rock Region, including all the beds that are relied on for a supply of ore for the greater number of furnaces in this iron district. (For an intelligent account of these ores, see Mr. Moore's Report on the Iron Ores of Greenup, Carter, &c., Part III, Vol. 1, New Series, Reports on the Geology of Kentucky.)

The accompanying map will serve to give a more definite notion of the location of the cannel coal district in question. The dotted outline is only intended to give an approximate boundary, as sufficient work has not been done to make a definite boundary possible. The profile section gives a good notion of the place of the various beds of coal and of iron ore, in their relation to the drainage, and in their relation one to another.

APPENDIX.

The equivalency of the upper beds of the general section of Northeast Kentucky with those of Ohio is pretty well established. Coal 9, as shown opposite the mouth of Garner Creek, is the same as the Bagley's Run coal, or No. 7 of the Ohio report. Coal No. 8, Hatcher and Garner Creek, is also the Hatcher coal of Ohio, or No. 6B. No. 7, the Coalton seam, is in Ohio the Sheridan, the Nelsonville,* &c., or No. 6.

Coal 6, the Keyes Creek seam, is known in Ohio as the New Castle coal.

The ores and limestones associated with these coals are also readily recognized as equivalent beds; but below the horizon of the ferriferous limestone the correspondence with the beds of the Ohio section is not so clear, and, indeed, not so well defined as would be expected from the relation of the two fields, and from the comparatively slight variation from the typical section over a wide extent in Kentucky in the belt representing the lower part of the coal-measures. This is doubtless owing somewhat to the fact that the Ohio coal field has been more carefully studied in its northward extension, and that the general section is a better type of the geology northward than along the Ohio river.

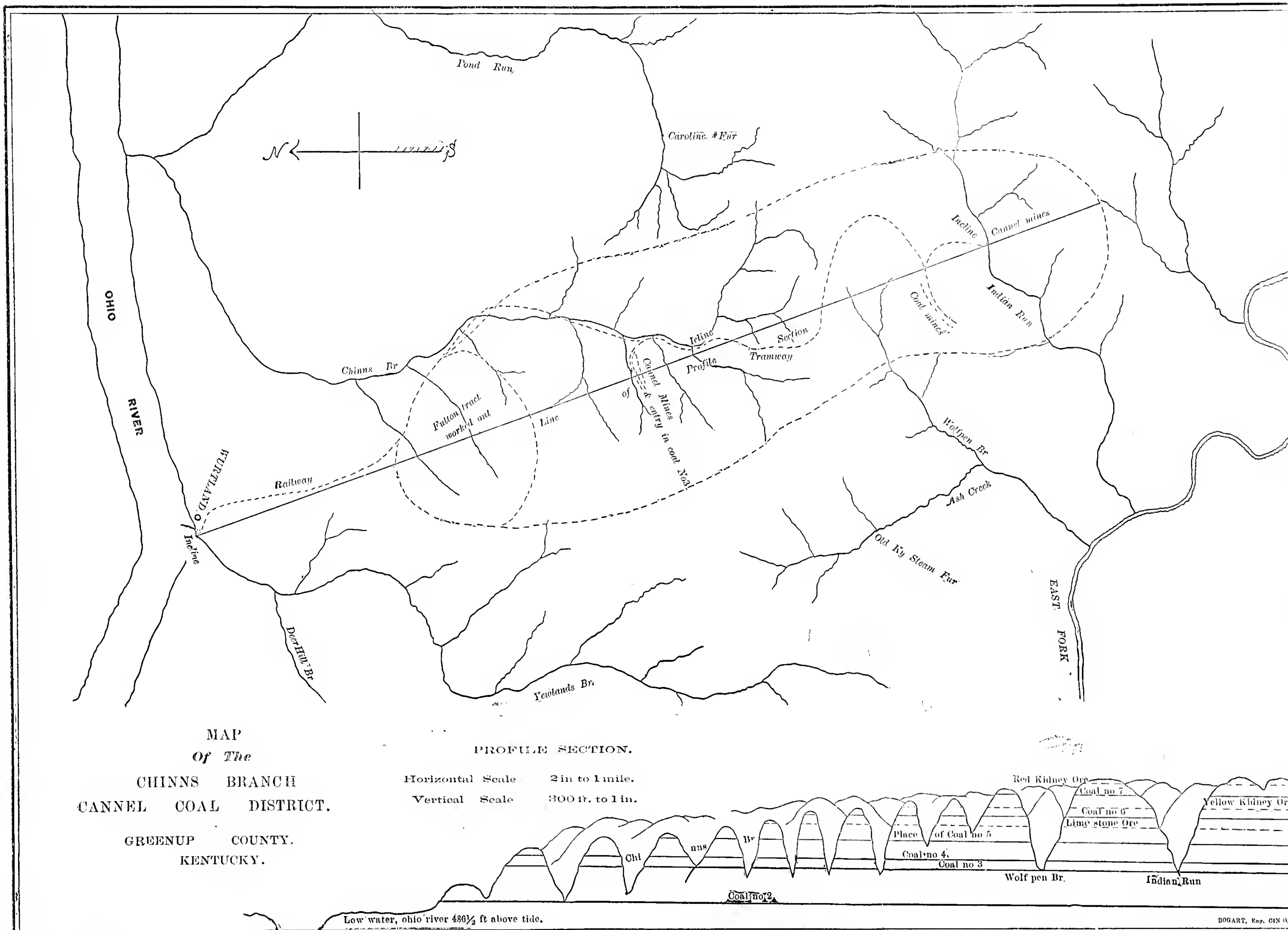
It is probable that a general correspondence with the Kentucky beds exists for a considerable distance into Ohio, though less definite and probably more limited in its northward extension than that of the series above Coal 5. The Conway coal, No. 3C of Ohio, probably represents Coal No. 5 of Kentucky; and the Kelly coal, No. 3A, and the Wilbur coal, No. 3, may provisionally represent Coals 4 and 3 of Kentucky, the

* The Ohio Report of 1870 placed the Nelsonville seam immediately under the ferriferous limestone below Coal 6 of the Kentucky section; and in volume II, Report on the Geology of Greenup, Carter, &c., a thin coal, noted on Pea Ridge, at Pennsylvania Furnace, and at several points in the East Fork valley at this horizon, was spoken of as the equivalent of the Nelsonville coal. A subsequent visit to the Hocking valley made it clear that the Nelsonville and Straightsville coal seam occupies the place of the Coalton. The report of Professor Orton, of the Ohio Geological Survey, on the Geology of the Hanging Rock District (Vol. III), confirms this view.

Hunnewell or Chinn's Branch, and the Turkey Lick or Peach Orchard.

The place in our section of the Jackson shaft coal is a matter of considerable uncertainty. If, as is held in Volume III, Geology of the Hanging Rock District, this is an inter-conglomerate bed, then its probable equivalent in Kentucky is the Proctor coal of Lee county. If, as later observations seem to show, the conglomerate below this coal is a subcarboniferous deposit, and that above the true coal-measure conglomerate, then this coal is the probable equivalent of the Menifee coal, and of the thin bed found in Greenup and Carter below the conglomerate, when that is present, and closely associated with the great non-plastic fire-clay bed of these counties. In either case, the Jackson Hill or the Wellston coal would be the same as No. 1 of the former Report on the Geology of Greenup, Carter, Boyd, and Lawrence.

If this view is correct, several thin beds from two to four in number, between the Wellston and No. 3, the Wilbur of Ohio, would be set over against No. 2 and 2A of Kentucky. To this there is no special objection, since the additional beds are found at considerable distance from the Ohio river, and may be regarded as local beds.



MAP
Of The
CHINNS BRANCH
CANNEL COAL DISTRICT.
GREENUP COUNTY.
KENTUCKY.

INDEX.

[The figures refer to the bottom paging.]